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Bacillus thuringiensis

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Characterization of Lateral Spray Deposit Using Two Aerially Applied Formulations of Bacillus thuringiensis

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Foreword

This report is published as a part of the USDA Forest Service program to improve aerial application of insecticides, specifically to apply insecticides more effectively and efficiently to eastern broadleaved forests. The program is supported through the efforts of the Northeast Forest Aerial Application Technology Group (NEFAAT). This Group is composed of members from the USDA, Forest Service, Northeastern Area State and Private Forestry, and Northeastern Forest Experiment Station, Research Work Unit 4502; Animal and Plant Health Inspection Service (APHIS)-Gypsy Moth Methods Development Laboratory and -Aircraft Operations; and the Department of Entomology, Pennsylvania State University. Through cooperative efforts, the Group conducts field and laboratory studies to solve common problems associated with the application of microbial and chemical insecticides. The Group also provides technical assistance in conducting training sessions to improve the quality of operational programs involving the aerial application of insecticides.

The NEFAAT Group has conducted six studies at the APHIS-Aircraft Operations Facility in Mission, Texas, from February 1985 through January 1989. Information provided in this Technical Publication is based on field activities conducted between September 17 and 20, 1985, and represents the sixth in a series of six publications.

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Introduction

In the last decade, public awareness concerning the use of pesticides in agriculture and forestry has prompted careful examination of the benefits and risks associated with their application. All sources of pesticide contamination in the environment are being evaluated, including ground water leaching, surface run-off and off-target lateral displacement or "spray drift".

The nature of the forest canopy and the vast areas requiring treatment in forests necessitate the use of aircraft to apply insecticides. Unfortunately, the aerial application of insecticides to forests is particularly susceptible to the influence of local weather above and within the canopy and choice of application equipment and may, under some conditions, produce off-target drift. Bryant et al. (1987) measured the fate of the microbial insecticide Bacillus thuringiensis Berliner var. kurstaki (Bt) applied to broadleaved trees and found up to 45% of the spray released was not accounted for by foliar or ground deposition within the spray plot. This fraction of the total spray was either deposited on tree trunks and branches and/or displaced laterally out of the spray plot prior to deposition.

It is, therefore, essential to gather data which documents the extent of this off-target displacement using the aerial application equipment typically used to apply Bt during Federal/State/County cooperative suppression programs for gypsy moth, Lymantria dispar (L.) The objective of this study was to quantify the on-target and off-target fate of water- and oil-based formulations of Bt.

Materials and Methods

Location. Experimental runs were conducted at the USDA-Animal and Plant Health Inspection Service (APHIS), Aircraft Operations facility (Moore Airbase, Mission, TX). This site provided a large area of flat terrain with a short grass surface and few obstacles that might produce undesirable wind disturbances. Applications were made between September 17 to 20, 1985.

Formulations. Two commercial Bt formulations were selected. Both formulations have been commonly used in gypsy moth suppression programs, each having different physical properties at the same concentration of Bt per liter of final spray mixture. All applications were at a rate of 7.01L /ha (96 fl oz/ac) and dose of 30.0 Billion International Units (BIU) per ha (12 BIU/ac). The two formulations were as follows:

a. Thuricide 48LV (Sandoz Crop Protection, Wasco, CA), an aqueous flowable formulation containing 12.68 BIU/L (48 BIU/gal) which was diluted 1 part Thuricide to 2 parts water, and

b. Dipel 8L (Abbott Laboratories, Chicago, IL), an oil-based (EC) formulation containing 16.91 BIU/L (64 BIU/gal) which was diluted 1 part Dipel to 3 parts water.

Aircraft and Atomization. Applications were made with a Cessna Agtruck C188 (supplied by APHIS) which was equipped with 34 Spraying Systems 8004 flat fan nozzles oriented 45° forward. All applications were planned to be made perpendicular to wind. However, because the direction of the collector lines was fixed, all runs were made with variation in the degree of crosswind. The Agtruck was calibrated for a 22.9 m (75 ft) lane separation, speed of the aircraft was 193 kmh (120 mph) and flew at 15.3 m (50 ft) above ground level (agl). The flowrate was 51.5L (13.6 gal) per minute, pressure at 40 psi, and the spray was turned on and off approximately 456 m (1500 ft) before and after the collection lines.

Meteorological Data. All equipment for monitoring weather was located along the 366.4 m (1200 ft) downwind sampling line. A tethersonde mounted on a directional balloon relayed weather data by radio telemetry to a ground station (Atmospheric Instrument Research, Boulder, CO), for temperature and wind speed and direction at 9.5 m (30 ft) agl. Temperature, humidity, and wind speed and direction were recorded during applications at 0.92 m (3 ft) agl, and temperature at ground level.

Samplers. A 3-dimensional sampling space was constructed which would extensively sample the lateral displacement downwind with collectors positioned at 0.92 m (3 ft) agl for all distances downwind, and on vertical string lines positioned at three distances downwind, 244.3 m (800 ft), 366.4 m (1200 ft) and 488.5 m (1600 ft) (figure 1). Three replicate sampling lines (A, B, C) were used with two or three of each collector per sampling station located on each line at geometrically increasing spacings 30.5 m (100 ft), 61.6 m (200 ft), 122.1 m (400 ft), 244.3 m (800 ft), 366.4 m (1200 ft), 488.5 m (1600 ft), and 914.4 m (3000 ft) from the flight line.

Microbial insecticides, due to intrinsic characteristics, are difficult to collect and assay quantitatively and since there are few standard devices for sampling, we evaluated six sampling devices: 1) horizontal glass slides (GS), 7.5 cm X 2.5 cm (3.0 in diameter X 1.0 in); 2) vertical small cylinders (SC) with a Kromekote card as a collecting surface, 1.27 cm X 16.51 cm (0.5 in diameter X 6.5 in); 3) Coarse Aerosol Flag Samplers (EK) consisting of a Kromekote collecting strip 3.81 cm X 0.32 cm (1.5 in X 0.125 in) mounted on a wire which always oriented it into the wind via a wind-vane and the wire inserted into a 0.64 cm (0.25 in) diameter wooden dowel (designed by R. Ekblad, Missoula Equipment Technology Center, Missoula, Montana); 4) vertical plastic straws (PS), 19.5 cm X 0.5 cm (7.75 in X 0.25 in diameter); 5) horizontal Kromekote cards (CH), 16.51 cm X 10.80 cm (6.5 in X 4.25 in); and 6) suction filters (SF) (Falcon sterile, disposable 150 ml filter units with attached pumps calibrated with 1L /min) (Reardon et al 1990). The SC, EK, PS, and SF sampling devices were chosen to give high collection efficiency for fine (less than 100 um) droplets in the downwind spray region. The sampling devices were placed on wire stakes at 0.92 m (3 ft) agl while vertical profiles were sampled using the plastic straws (PS) suspended at 3.05 m (10 ft) intervals up to 30.5 m (100 ft) on a string held vertically by a helium balloon. Horizontally oriented Kromekote cards (Mead Corporation, Dayton, OH) were used to characterize the spray deposit pattern beneath the aircraft and extended near-range downwind to 76.2 m (250 ft) where deposit is comprised of the larger droplet fraction dominated by sedimentation.

Deposit data was measured using tracer washoff on the EF, SC, and GS sampling devices at 0.92 m (3 ft) agl for downwind deposit measurement, and on the PS sampling device in the vertical sampling profile. The deposit on the EK was also measured with an Optomax V image analyzer (Analytical Measuring Systems, Essex, England) to determine droplet size and density at various distances downwind. The average of the volume median diameters (VMD's) across the replicate sampling lines at a given distance was combined with data on wind speed at 0.92 m (3 ft) and collector diameter to estimate a collection efficiency for the EK. Because the droplet spectrum width was narrow at various distances downwind, the average droplet size at a given distance was assumed not to be biased by the catch efficiency of the EK; only the absolute number of droplets would be affected. Using this assumption, the droplet sizes caught by the EK could be assumed to closely represent the actual droplet size present in the airborne spray. All deposit on the EK was then increased according to the collection efficiency in an attempt to represent the airborne spray concentration not just the concentration collected. No attempt was made to correct the collection efficiency of the Kromekote cards (CH); it was assumed that the low wind speed and large droplet size in the region directly beneath the aircraft would ensure very high collection efficiency through sedimentation, with little influence due to impaction through turbulence.
Spray deposit was measured using the fluorometric tracer brilliant sulfaflavine (Organic Dyestuffs, East Providence, RI) added to the final spray mix at 2.5 g/liter. Measurements were performed by washing the tracer from the samples for 1 hour in 30% methanol:water solution using a wrist-action shaker and measuring the fluorescence of the elute (Goering and Butler, 1974). Samples were taken from the spray boom after each application to establish the exact ratio of tracer to active ingredient in the spray mix. Data from runs which used 5 passes in alternate directions to increase deposit levels and average out the instantaneous variations in weather have been divided by 5 to return the deposition to comparable units to single passes.

A summary of treatments for each spray run is shown in Table 1.

Table 1. Summary of treatments for each spray run conducted at Mission, TX, 1985.

Run #	Product	Passes	Date	Time (am)
1	Thuricide 48 LV	1	9/17/85	4:40
2	Thuricide 48 LV	1	9/17/85	7:08
3	Thuricide 48 LV	1	9/18/85	2:18
4	Thuricide 48 LV	5	9/18/85	4:46
5	Thuricide 48 LV	1	9/18/85	7:30
6	Thuricide 48 LV	5	9/19/85	2:30
7	Dipel 8L	1	9/19/85	6:30
8	Dipel 8L	1	9/20/85	1:44
9	Dipel 8L	1	9/20/85	4:22
10	Dipel 8L	5	9/20/85	6:56

Results

Inclement weather, with high daytime wind speeds throughout most of the study prevented consistent use of normal application timings, i.e., early morning or evening. Therefore, many runs were made at night with the aid of portable lighting. The resulting high humidities, calm winds and rising temperatures with height provided very stable boundary layer conditions (Table 2). These stable conditions

Table 2. Summary of weather conditions for each spray run conducted at Mission, TX, 1985.

Run	Wind Speed/Direction (MPH)				Relative Humidity (%)	Temperature (° F)		
	3'		30'		3'	0'	3'	30'
1	2	10°	6	30°	88	71	69	73
2	<1	—	6	45°	88	71	69	73
3	2	120°	8	140°	87	74	73	77
4	2	105°	7	120°	87	74	72	76
5	1	105°	5	120°	86	73	71	75
6	<1	—	4	135°	88	75	72	76
7	3	65°	6	75°	87	73	71	75
8	<1	—	3	80°	87	75	72	76
9	<1	—	6	75°	88	74	71	75
10	<1	—	2	105°	85	74	71	75

have been shown to be conducive to drift because of the lack of turbulent transport to deliver small droplets to the target surface. While these stable conditions are not beneficial to turbulent transfer of small droplets, the low wind speeds and high humidities prevented large scale off-site movement of spray.

All deposit data shown are in units of nanoliters (nl) of tank mix per square centimeter. Each nanoliter of spray contained 4.2 IU of Bt toxin which is equivalent to 30 BIU/ha (12 BIU/ac) applied in 7.0L /ha (96 fl oz/ac). The area of the collecting surface was calculated as the horizontal area for the Kromekote cards (CH) and glass slides (GS) and as a silhouette area for the plastic straws (PS), small cylinders (SC), and coarse aerosol flags (EK).

Spray Deposit Pattern

Deposit data collected on horizontal Kromekote cards (CH) at 0.92 m (3 ft) agl located beneath the aircraft and near-range downwind are only reported for three (3,6, and 8) of the ten runs in an effort to document the variability which might be encountered during trials to characterize an aircraft due to weather conditions at ground level and at the insecticide release height (Figures 2 a-c). Ideal crosswind conditions required a wind direction of 130 degrees. For run 3, the ground deposit pattern was displaced at least 125 ft to the downwind side of the flightline due to a strong crosswind component (140° and 8.0 mph) at 30 ft agl and slight component (120° and 2.0 mph) at 3 ft agl. Lighter crosswind components at 30 ft agl were evident for runs 6 and 8 (4.0 and 3.0 mph, respectively) as there was a reduced horizontal displacement of ground deposit. In all three runs, there was negligible wind (less than 2 mph) at 3 ft agl and stronger wind (3.0 to 8.0 mph) at 30 ft agl, which resulted in the peak of the deposit pattern being displaced at least 50 ft from the flight line. This demonstrates the risk of mismatched swath patterns in consecutive spray runs if the wind is light in strength and variable in direction at the ground level and the wind speed and direction is not monitored at canopy level or insecticide release height. Relatively high concentrations of spray can be moved short distances off-target if the position of the flightline is badly judged with respect to the plot boundary and the strength and direction of the wind.

Near- and far-range downwind spray deposit data collected at 0.92 m (3 ft) agl is reported in most cases for runs 3, 4, 5, and 6 (Table 3). These runs were selected as having favorable wind direction and greater number of operable collectors (e.g., moisture on the collectors limited deposit analysis). Complete data sets are unavailable for runs 8 and 10 because of poor stain contrast from the oil-based formulation of Dipel 8L and the subsequent inability to accurately measure droplet size with the image analyzer. Near- and far-range downwind spray data represent the deposit which was displaced a distance 30.5 m (100 ft) or greater downwind, as measured from the GS, SC, EK, SF and PS collectors. For the horizontal glass slides (GS), near- and far-range downwind deposit data are reported for runs 4, 5, 6, and 8 (Figures 3 a-d). In general, the peak deposit, expressed as nanoliters/sq cm, was recovered by the collectors at the 30.5 m (100 ft) and 61.0 m (200 ft) sampling stations and decreased with the downwind distance from the flightline. For the vertically positioned SC and EK collectors, deposit was corrected by the estimated collection efficiency based on the droplet sizes captured at a particular distance downwind and the horizontal windspeed. Collector dimensions were constant for each run. For the EK collectors, the estimated collection efficiency is shown in Table 3.

Droplet size, expressed as VMD, for the EK collectors decreased progressively downwind of the flightline as the larger and thus heavier fraction of the droplet spectrum fell out of the spray quickly leaving only the smaller droplet sizes airborne (Figures 4a-d). Downwind spray deposit profiles for the EK collectors, expressed as nanoliters/cm^2, show a progressive decrease in deposit, and hence airborne concentration, with distance from the flightline (Figures 5 a-f). This progressive decrease in deposit was also evident for the SC collectors (Figures 6 a-e). For the EK collectors, a logarithmic transformation yields near linear relationships between log distance downwind and log deposit (Figures 7 a-c). These data indicate a geometrically decreasing airborne concentration of insecticide at 0.92 m (3 ft) above ground level downwind from the release source. Other workers have demonstrated similar results from both ground and aerial applications (Yates et al. 1974; Frost and Ware 1970; Ware et al 1972) and drift modeling (Barry and Ekblad 1983). These data show that most of the spray has deposited by 304.8 m (1000 ft) from the flight line even under these adverse stable conditions. The

Table 3. Summary of droplet size, expressed as volume median diameter (VMD), and collection efficiency[a] for the coarse aerosol flag samplers, Mission, TX, 1985.

Run	Distance (ft)	Volume Median Diameter (um) Mean	SE[b]	Collection Efficiency %
3	100	241.1	27.9	82
3	200	171.9	15.9	79
3	400	121.4	9.8	76
3	800	66.5	6.9	60
3	1200	53.7	7.1	55
3	1600	55.8	7.0	55
3	3000	36.5	8.3	30
4	100	208.0	18.3	80
4	200	155.6	15.3	77
4	400	115.0	8.9	76
4	800	87.5	7.8	71
4	1200	73.8	13.0	66
4	1600	35.7	6.3	25
4	3000	22.7	4.4	10
5	100	102.7	23.0	78
5	200	127.4	8.2	72
5	400	101.4	11.8	65
5	800	43.5	5.2	25
5	1200	31.7	2.0	15
5	1600	27.5	3.3	10
5	3000	23.4	3.2	10
6	100	151.6	6.0	74
6	200	134.1	9.9	72
6	400	94.6	7.5	62
6	800	55.8	4.6	25
6	1200	48.2	3.3	25
6	1600	45.5	1.8	25
6	3000	38.7	4.1	15

[a] Collection efficiency is calculated based on droplet sizes captured at A distance downwind and horizontal windspeed for each run.

[b] SE = standard error of the mean.

deposit data collected by the suction filters (SF) was erratic due to malfunctioning of the pumps within and among runs. This occurred in spite of efforts to initially calibrate and recharge the pumps prior to each run. The SF collectors are efficient collectors of fine (<100 um) droplets and were to be used as a comparison with the EK collectors.

Airborne concentrations of downwind spray deposit were also sampled vertically up to a height of 30.5 m (100 ft) using vertical plastic straws (Figures 8 a-f) and strings-the 3.3 m (10 ft) sections between straws (Figures 9 a-d). However, as previously seen, concentrations at these distances are reaching the limits of detection (i.e. above background levels) using passive collectors.

Conclusion

Under typical spraying conditions for broadleaved trees in the northeast, where winds will be encountered at canopy and spray release heights, there will be both a horizontal displacement in the main spray pattern as well as an exponential decay of the remaining airborne spray concentration. Although these series of runs were made with a crosswind to the flightpath, similar horizontal displacements can be expected when the aircraft is flown in the same direction as the wind. The influence of aircraft flight speed and direction are very quickly lost once a droplet is released. After release, the droplet's motion is dominated by sedimentation, aircraft wake disturbances, and the turbulence and horizontal movement of the overall airmass.

The concentration of the airborne fraction downwind of release is, however, many orders of magnitude less than the main deposit pattern beneath the aircraft, as seen by comparing the concentration recovered beneath the flightline (Figures 2 a-c) with the airborne fraction recovered some distance downwind (Figures 6 a-e). The environmental impact of such a concentration will depend of the sensitivity of the ecosystem and the toxicity of the displaced spray.

Because of the lack of droplet size data for runs 8 and 10, the Dipel 8L runs, it is not prudent to draw comparisons between Thuricide 48LV (aqueous flowable) and Dipel 8L (oil-based EC) applications.

Any perceived differences may be due to different droplet sizes at release or differences in weather during sedimentation and not due to any inherent property of the materials applied.

Future efforts to monitor off-target airborne concentrations of a microbial insecticide will require the identification and use of standard artificial samplers, and to evaluate the effects of drift, additional studies to establish the relationship between deposits on artificial samplers with deposits on natural collection surfaces. Suction filters or a similar type of active collector which is highly efficient for capturing fine droplets (less than 100 um) are essential and should be located at numerous distances within the 3-dimensional sampling space. Intensive monitoring of weather using sensitive equipment positioned at several horizontal and vertical distances downwind is also essential for the use of predictive models and efforts to explain the variation due to the interaction of weather variables between runs.

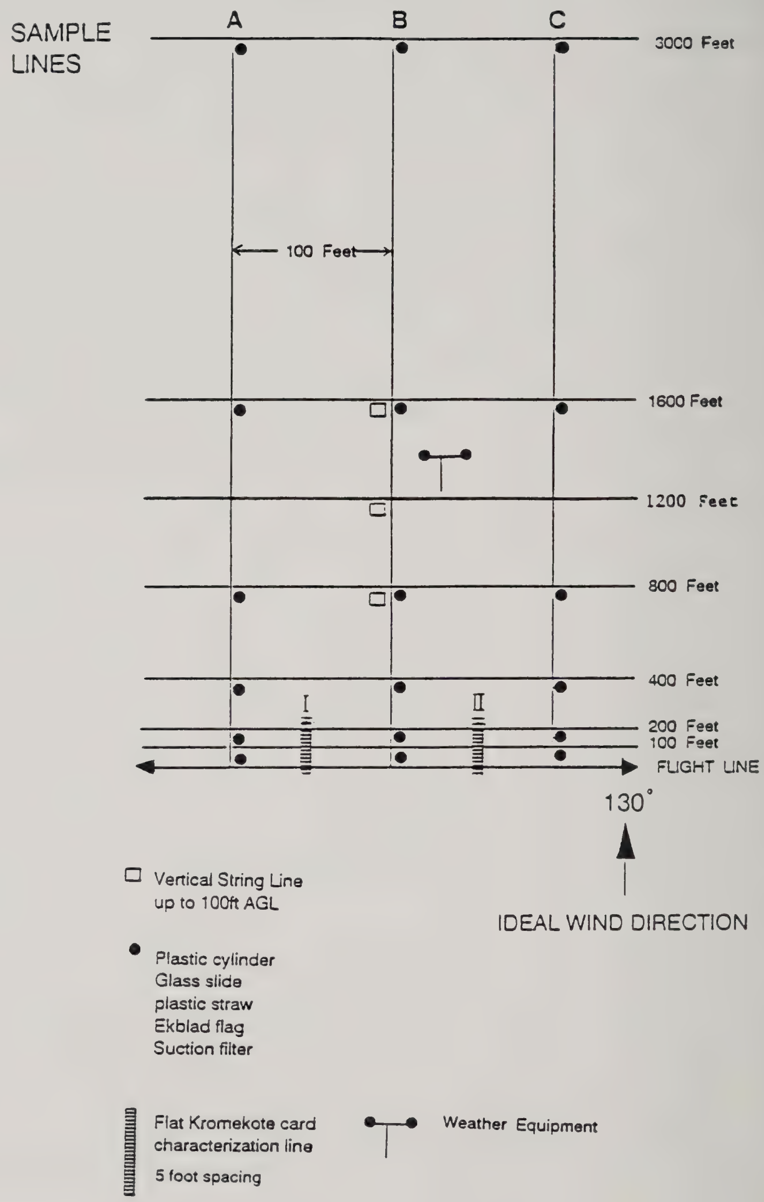

Figure 1: Experimental design for evaluation of *Bt* spray drift, Mission, TX - 1985

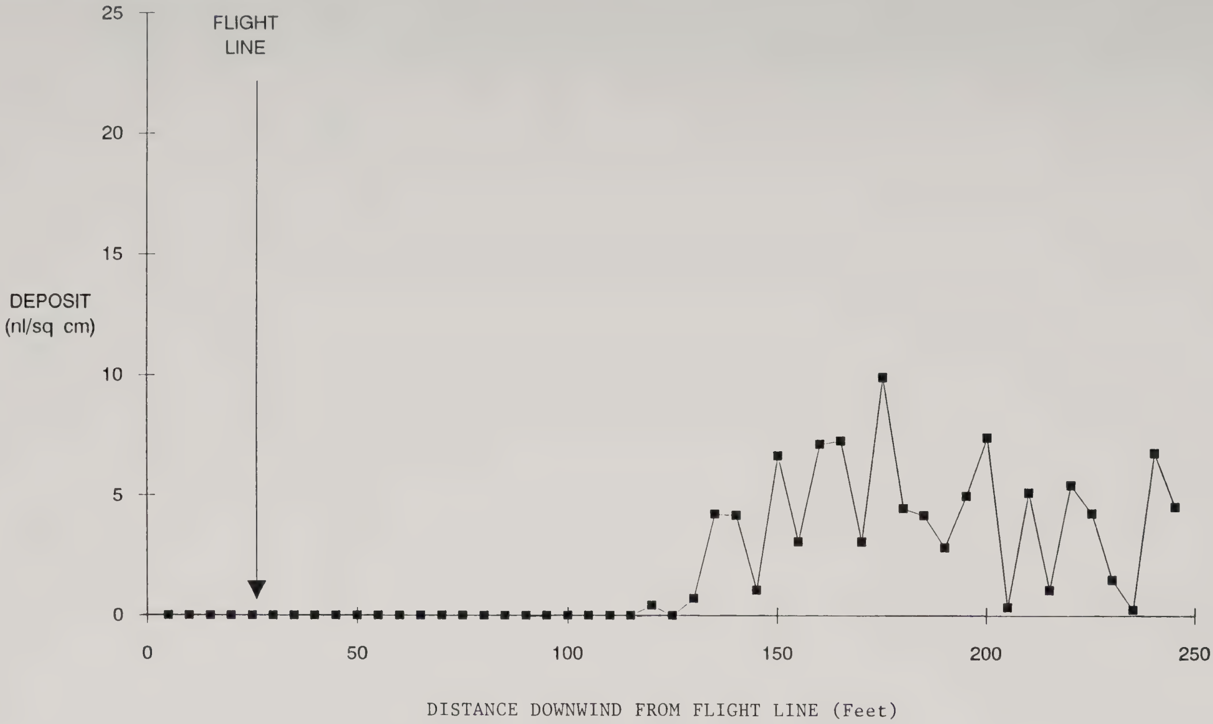

Figure 2a: Deposit data collected at 0.92m (3ft) above ground level using horizontal Kromekote cards for run 3 (Thuricide 48LV), Mission, TX - 1985

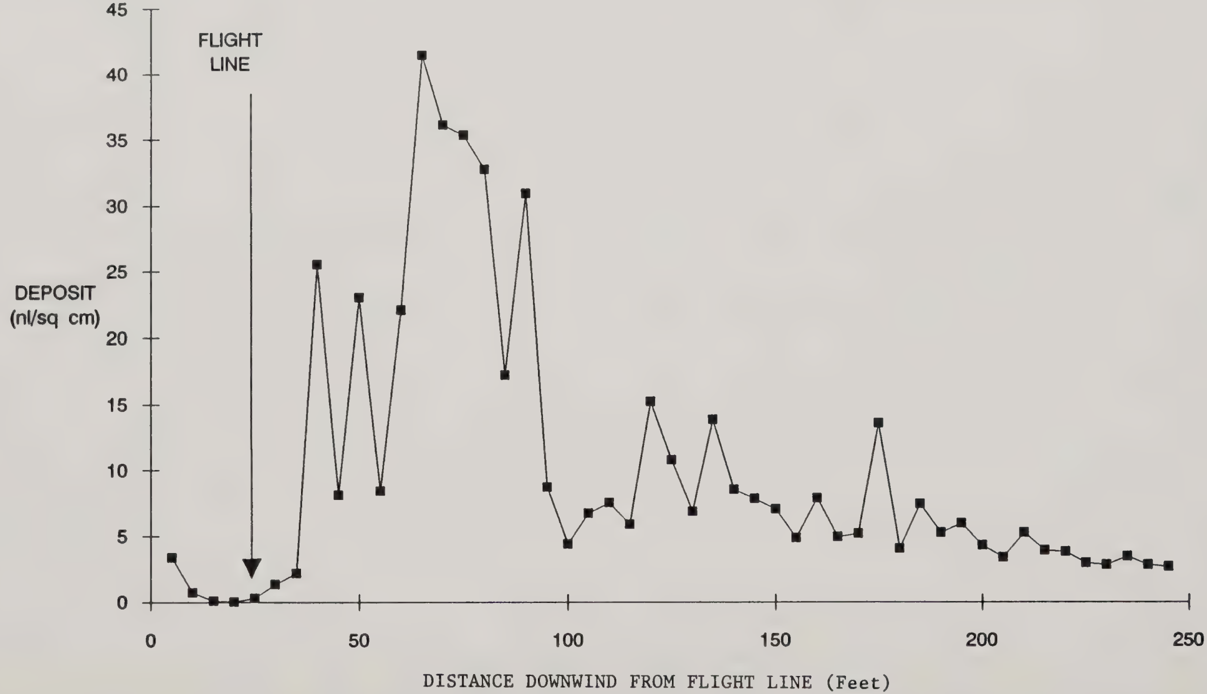

Figure 2b: Deposit data collected at 0.92m (3ft) above ground level using horizontal Kromekote cards for run 6 (Thuricide 48LV), Mission, TX - 1985

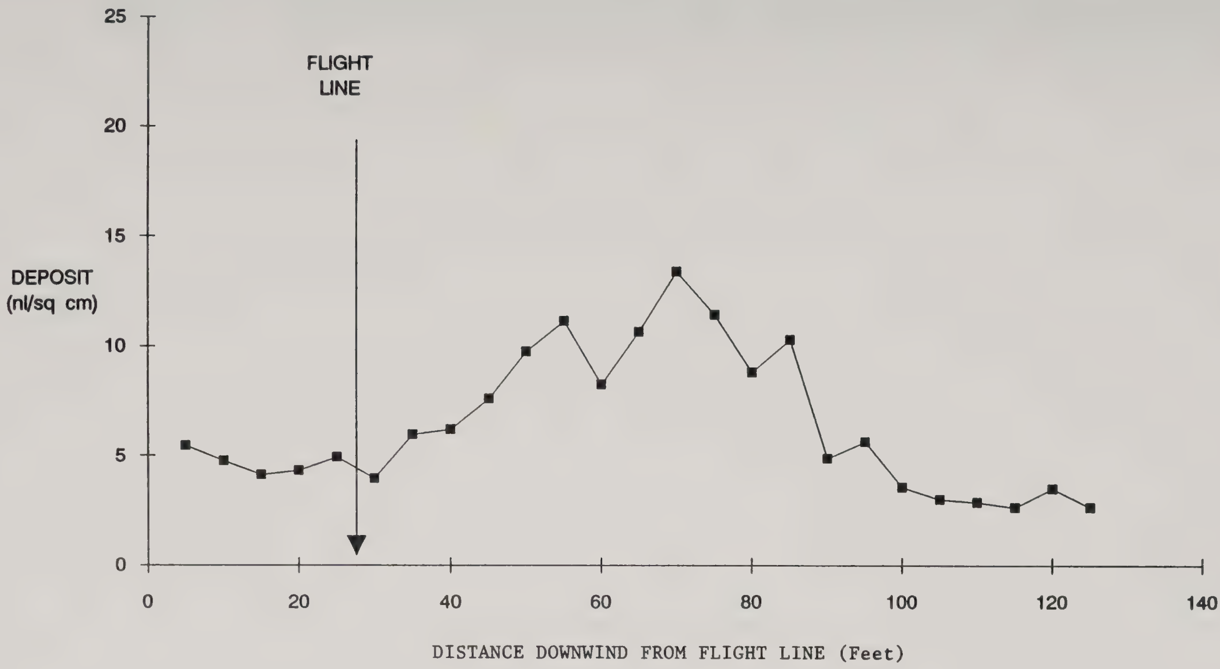

Figure 2c: Deposit data collected at 0.92m (3ft) above ground level using horizontal Kromekote cards for run 8 (Thuricide 48LV), Mission, TX - 1985

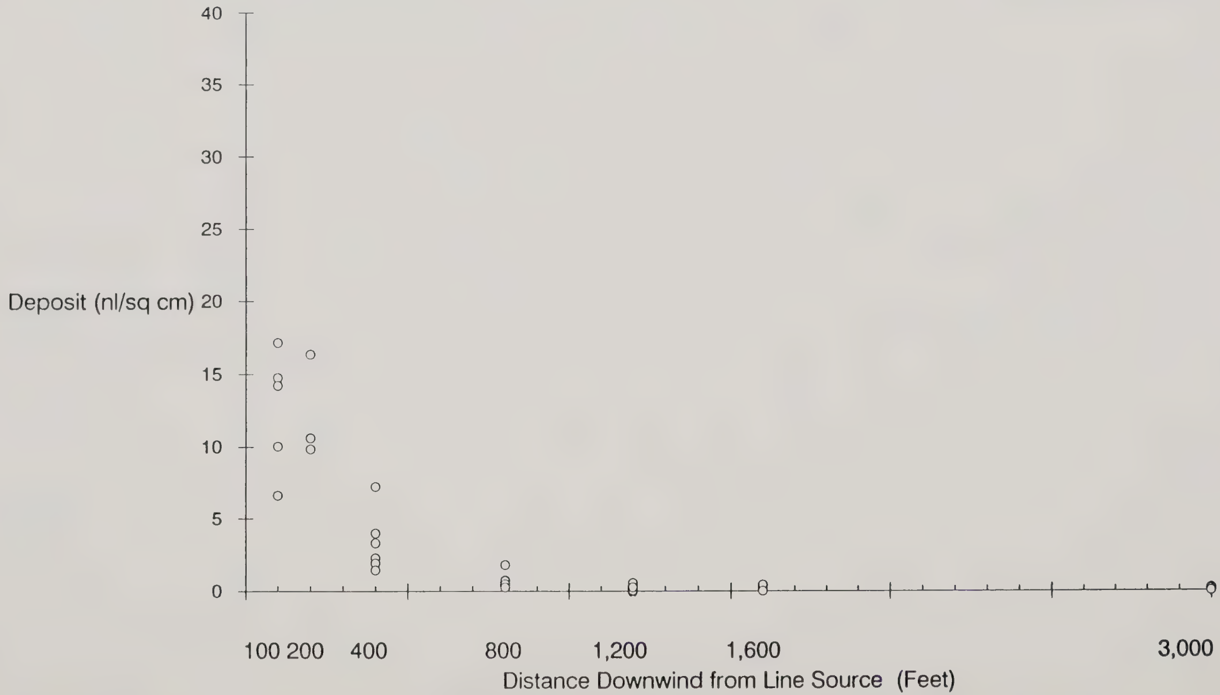

Figure 3a: Deposit data collected at 0.92m (3ft) above ground level using horizontal glass slides for run 4 (Thuricide 48LV), Mission, TX - 1985

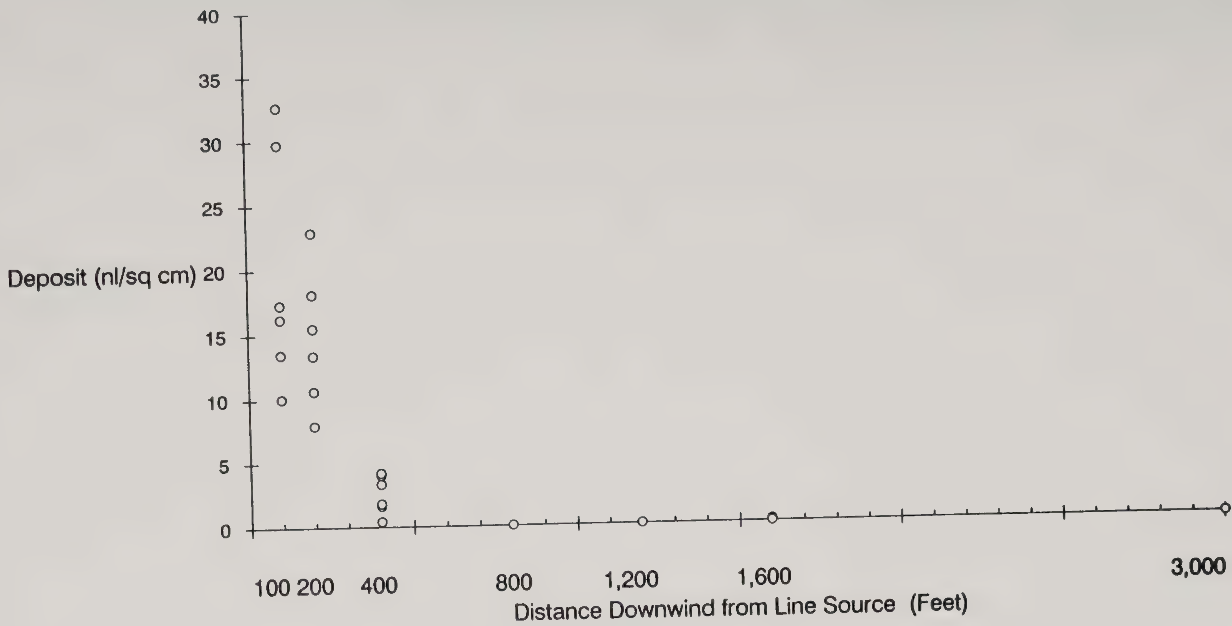

Figure 3b: Deposit data collected at 0.92m (3ft) above ground level using horizontal glass slides for run 5 (Thuricide 48LV), Mission, TX - 1985

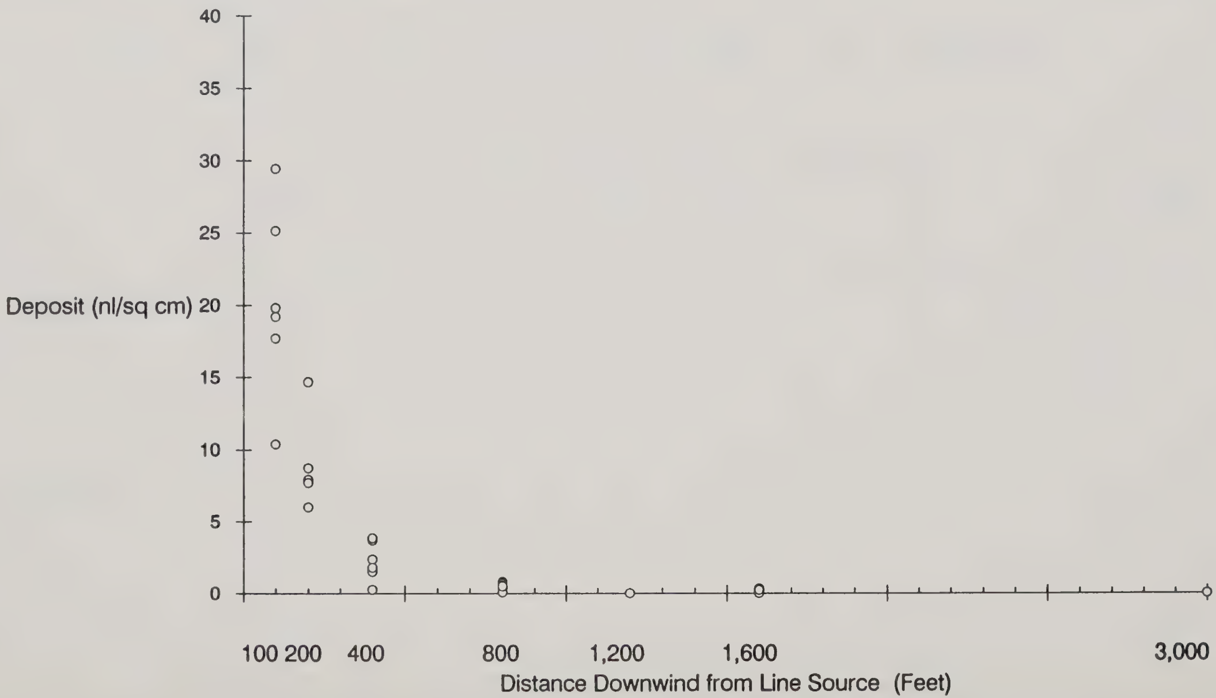

Figure 3c: Deposit data collected at 0.92m (3ft) above ground level using horizontal glass slides for run 6 (Thuricide 48LV), Mission, TX - 1985

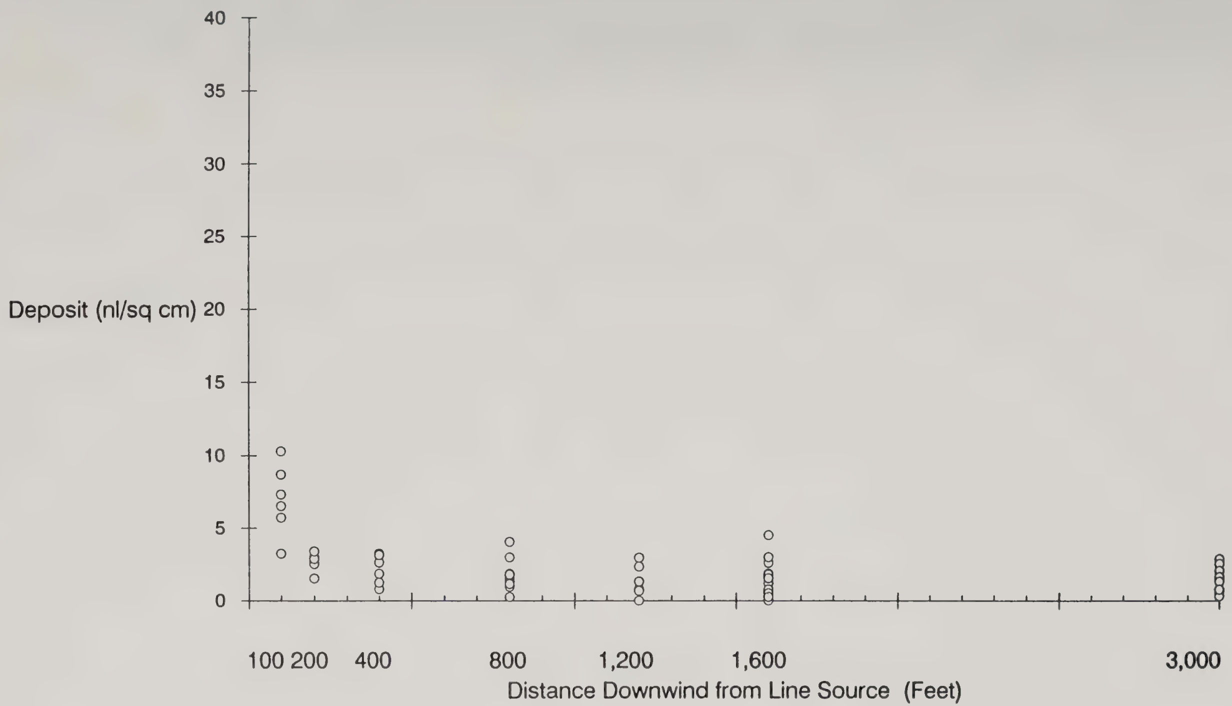

Figure 3d: Deposit data collected at 0.92m (3ft) above ground level using horizontal glass slides for run 8 (Thuricide 48LV), Mission, TX - 1985

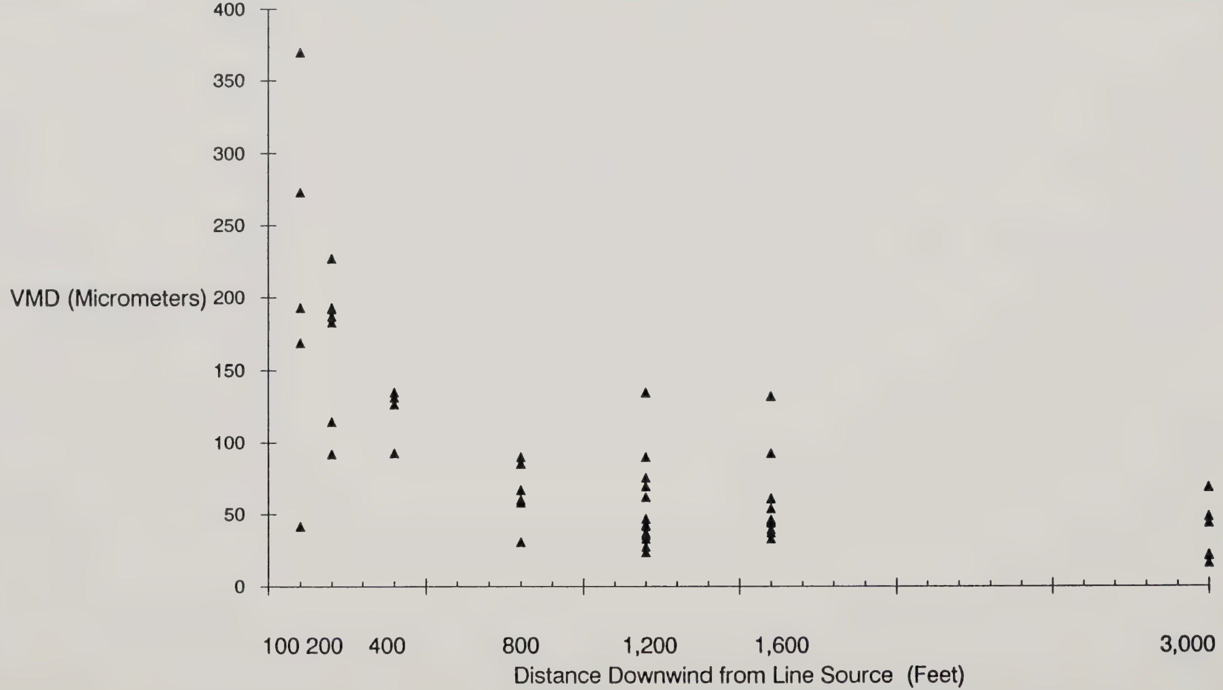

Figure 4a: Downwind spray deposit data expressed as volume median diameter ($DV_{0.5}$), using coarse aerosol flag samplers, and converted for collection efficiency, run 3, Mission, TX - 1985

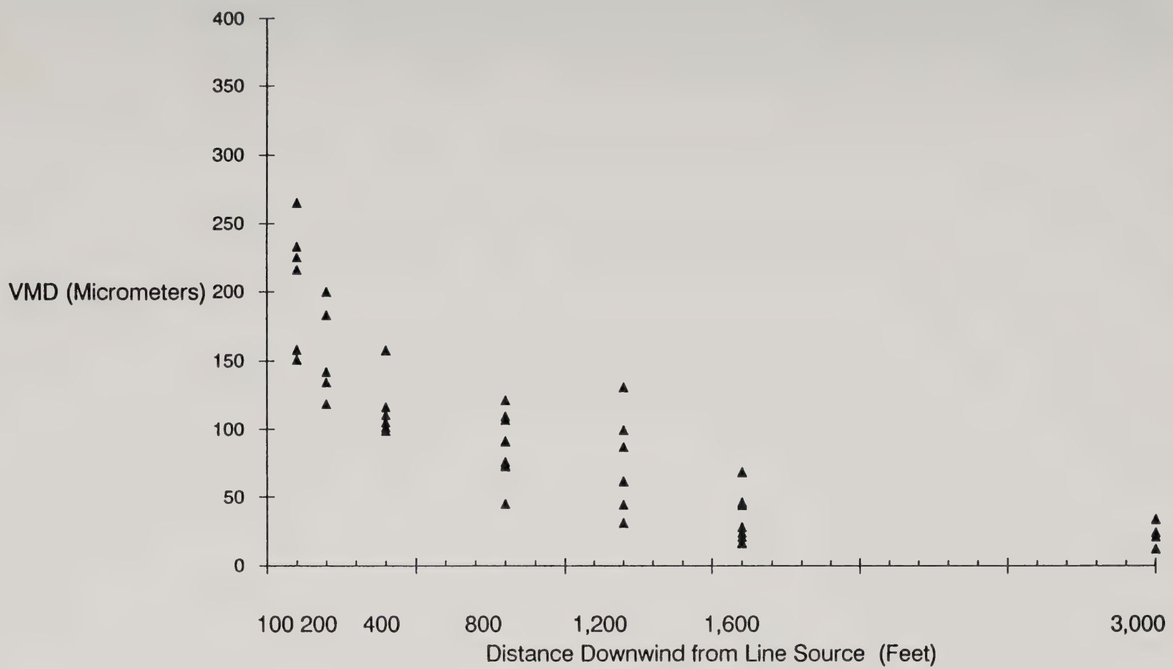

Figure 4b: Downwind spray deposit data expressed as volume median diameter ($DV_{0.5}$), using coarse aerosol flag samplers, and converted for collection efficiency, run 4, Mission, TX - 1985

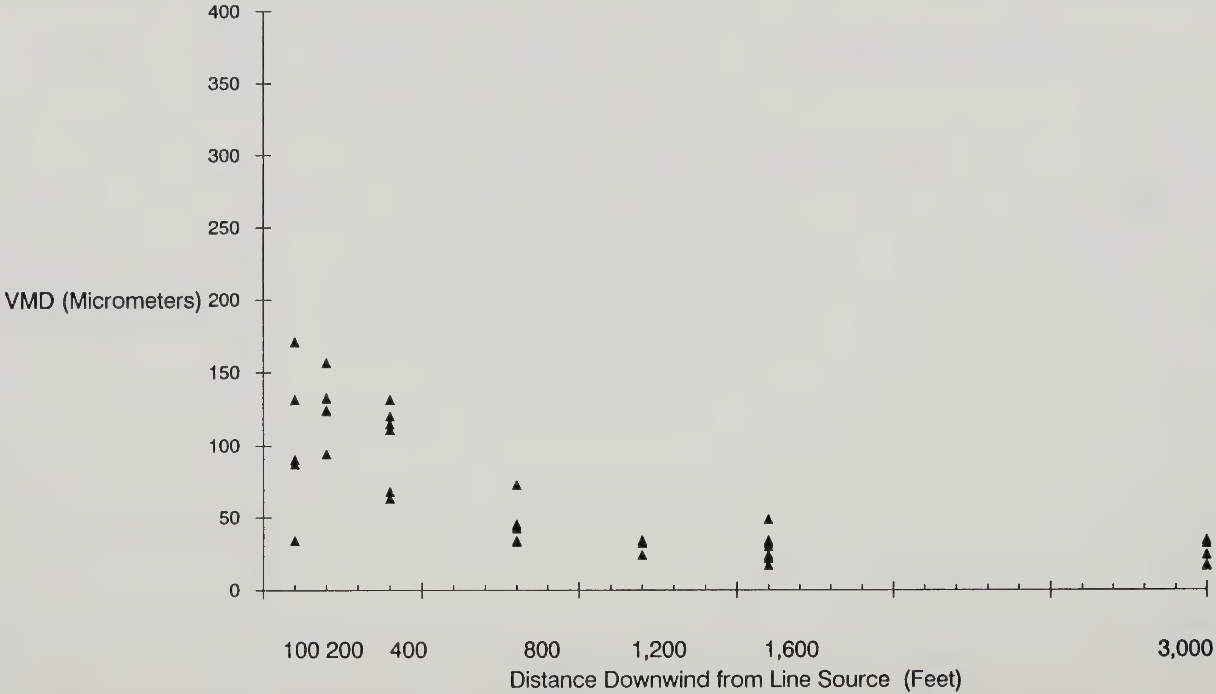

Figure 4c: Downwind spray deposit data expressed as volume median diameter ($DV_{0.5}$), using coarse aerosol flag samplers, and converted for collection efficiency, run 5, Mission, TX - 1985

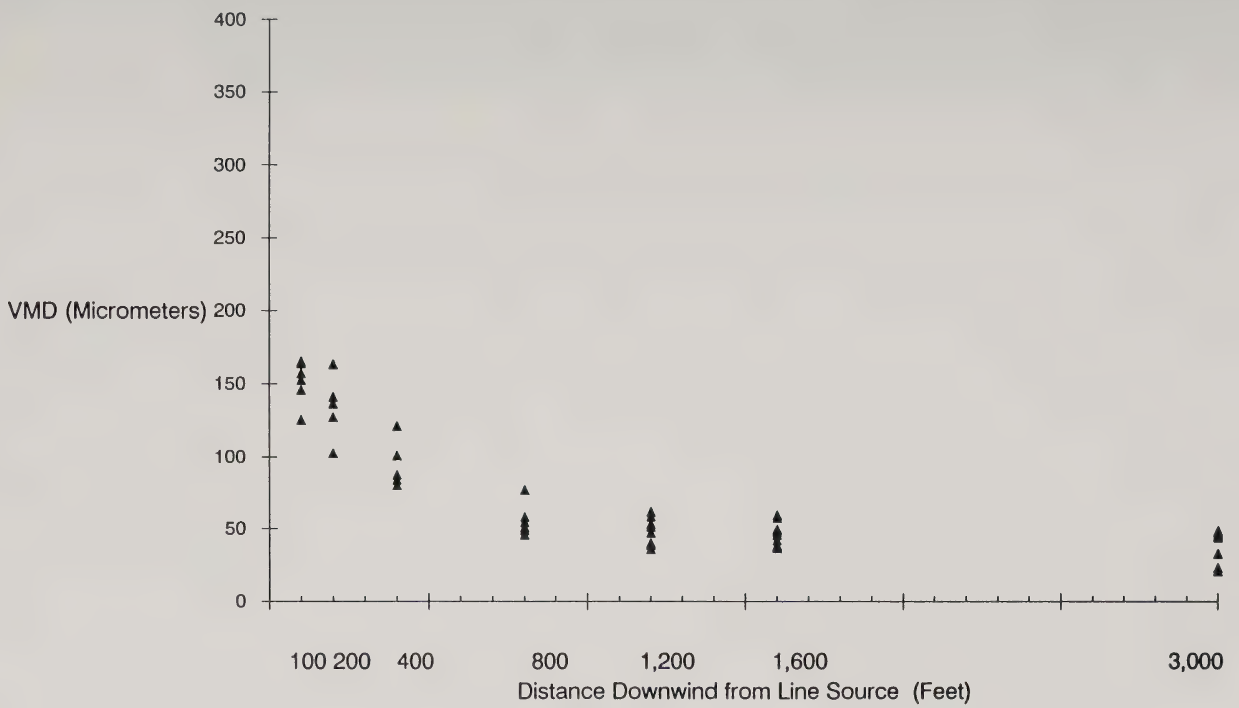

Figure 4d: Downwind spray deposit data expressed as volume median diameter ($DV_{0.5}$), using coarse aerosol flag samplers, and converted for collection efficiency, run 6, Mission, TX - 1985

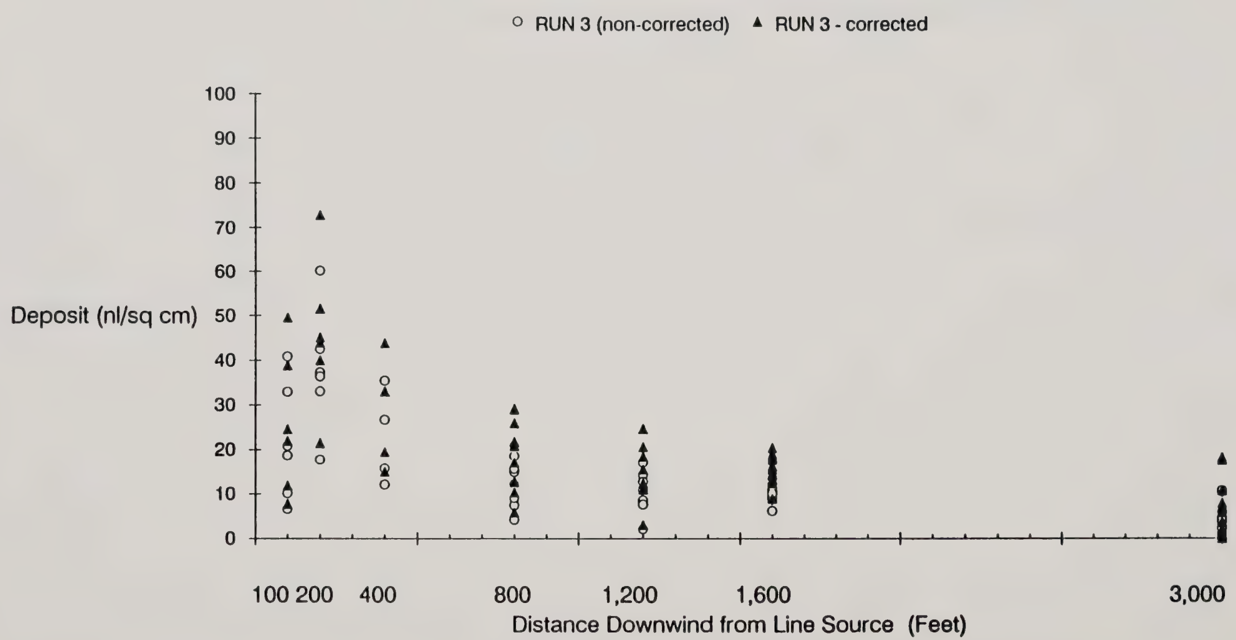

Figure 5a: Downwind spray deposit data expressed as nanolitres/cm^2, collected using coarse aerosol flag samplers, and converted for collection efficiency, run 3, Mission, TX - 1985

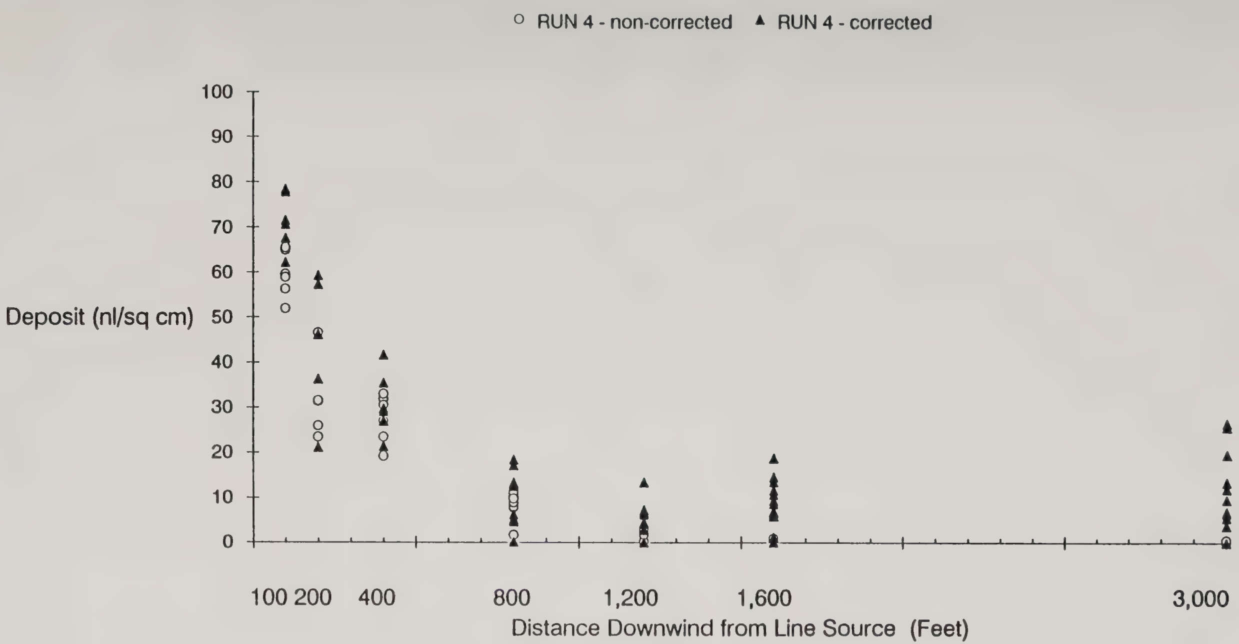

Figure 5b: Downwind spray deposit data expressed as nanolitres/cm^2, collected using coarse aerosol flag samplers, and converted for collection efficiency, run 4, Mission, TX - 1985

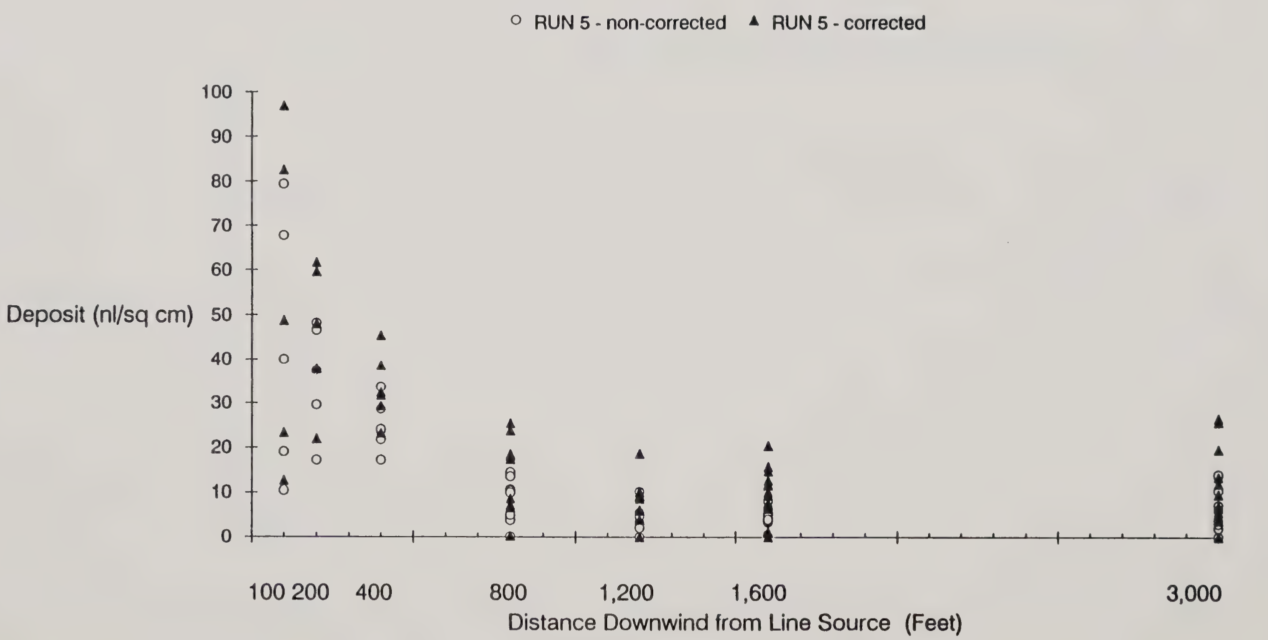

Figure 5c: Downwind spray deposit data expressed as nanolitres/cm^2, collected using coarse aerosol flag samplers, and converted for collection efficiency, run 5, Mission, TX - 1985

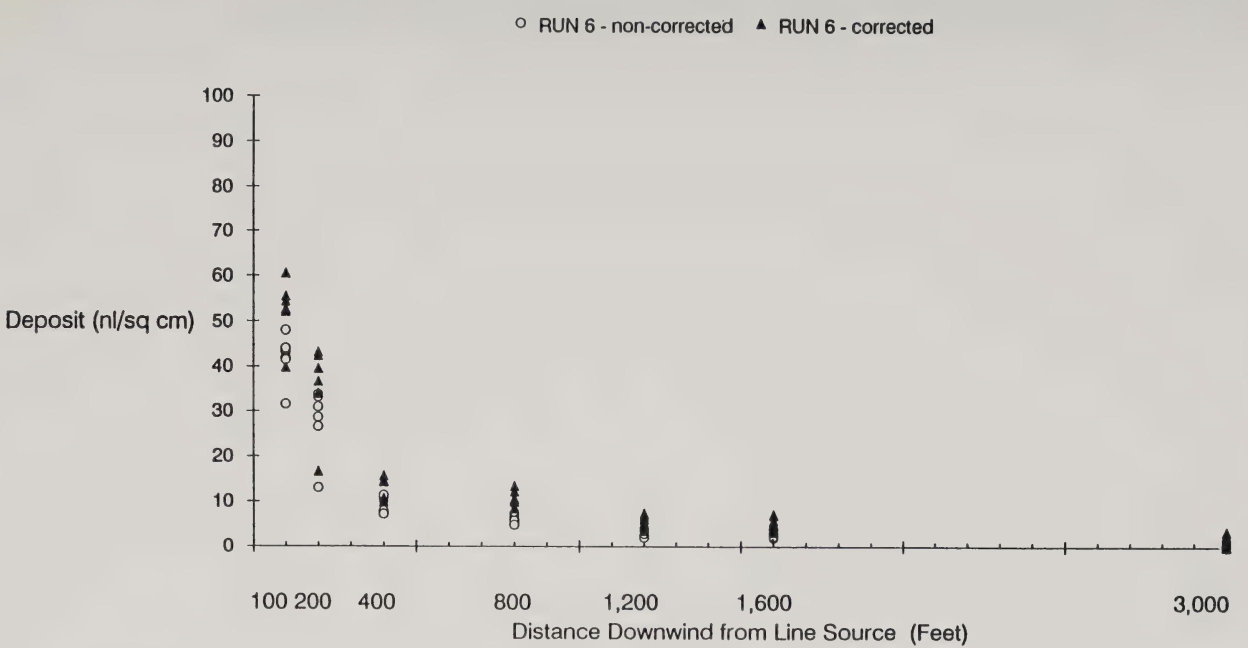

Figure 5d: Downwind spray deposit data expressed as nanolitres/cm^2, collected using coarse aerosol flag samplers, and converted for collection efficiency, run 6, Mission, TX - 1985

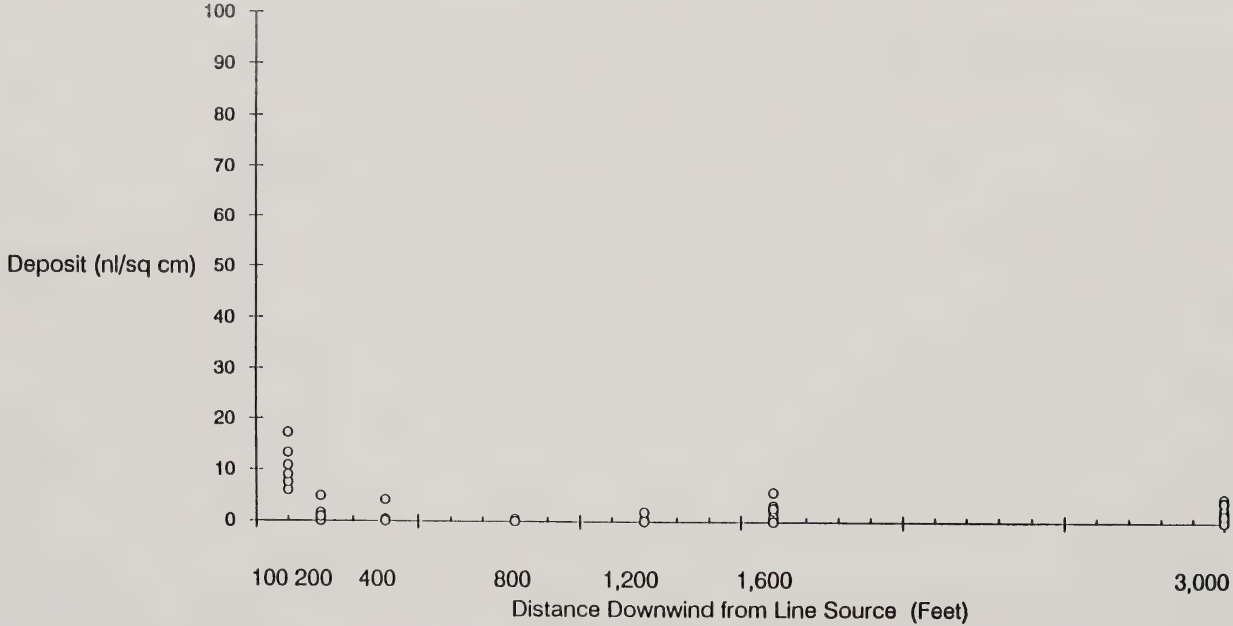

Figure 5e: Downwind spray deposit data expressed as nanolitres/cm^2, collected using coarse aerosol flag samplers, run 8, Mission, TX - 1985

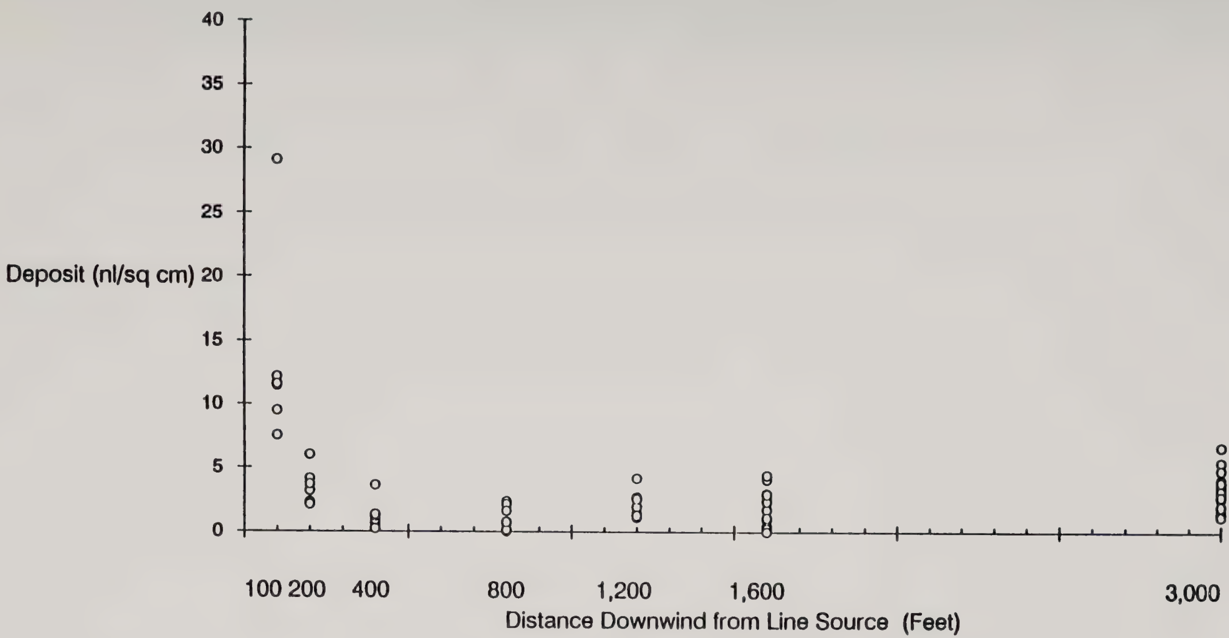

Figure 5f: Downwind spray deposit data expressed as nanolitres/cm^2, collected using coarse aerosol flag samplers, run 10, Mission, TX - 1985

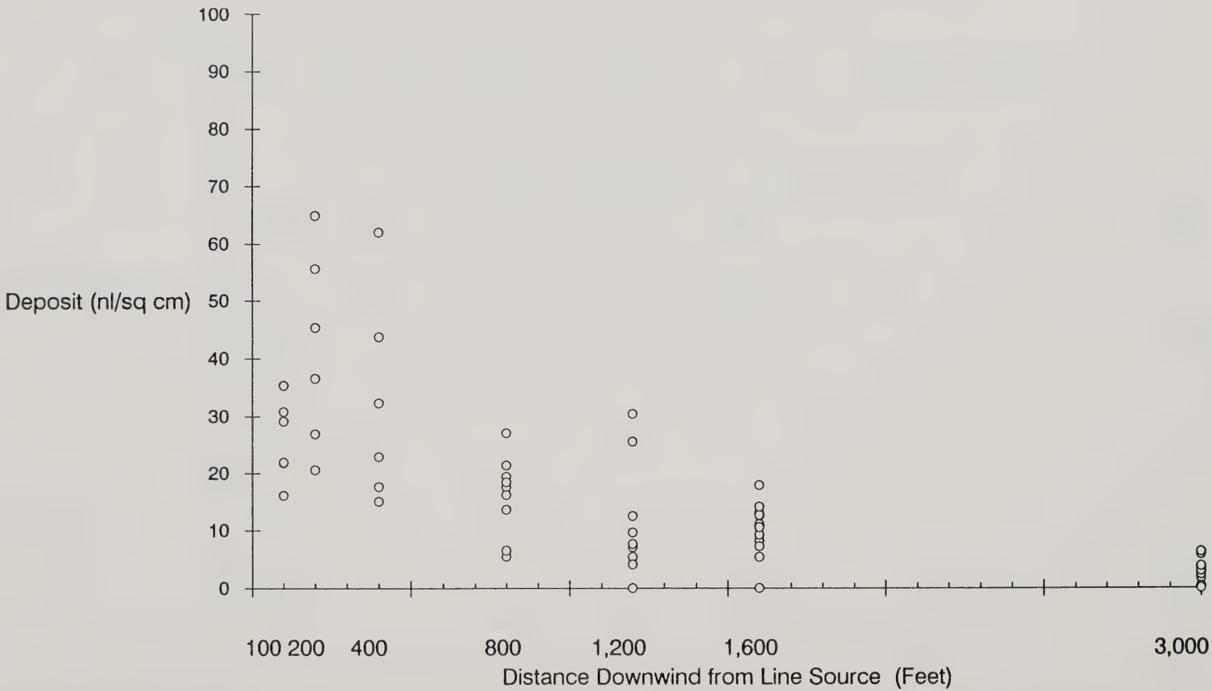

Figure 6a: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical small cylinders, run 3, Mission, TX - 1985

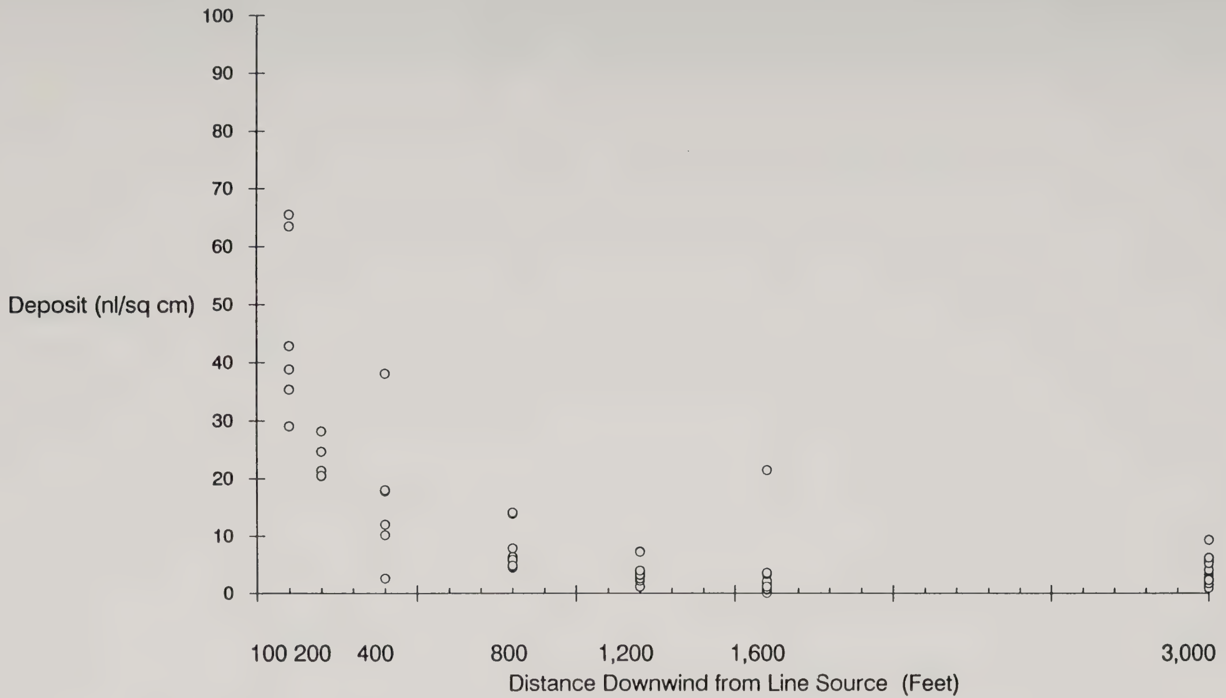

Figure 6b: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical small cylinders, run 4, Mission, TX - 1985

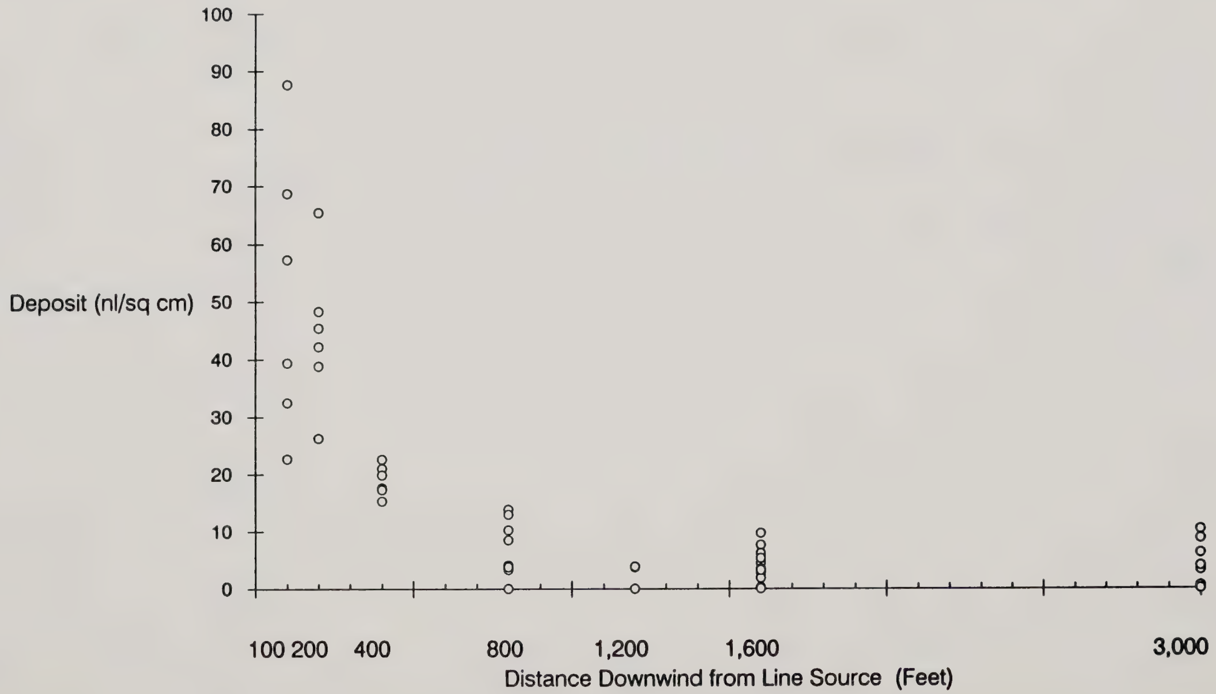

Figure 6c: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical small cylinders, run 5, Mission, TX - 1985

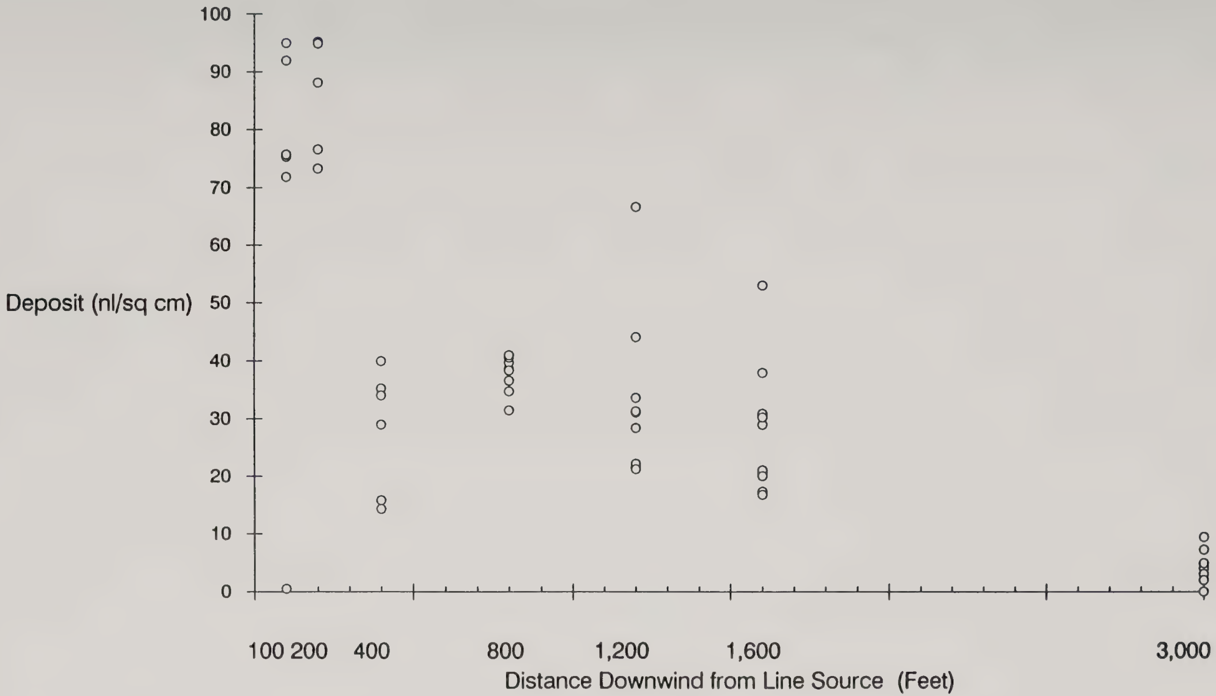

Figure 6d: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical small cylinders, run 6, Mission, TX - 1985

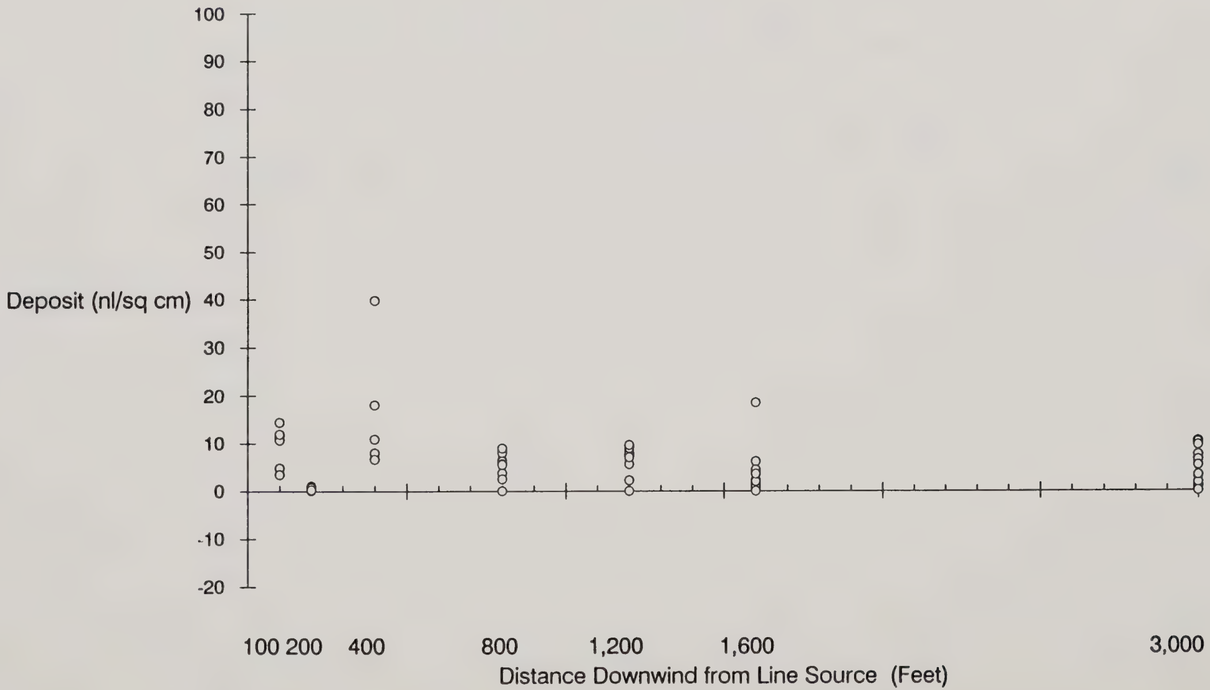

Figure 6e: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical small cylinders, run 10, Mission, TX - 1985

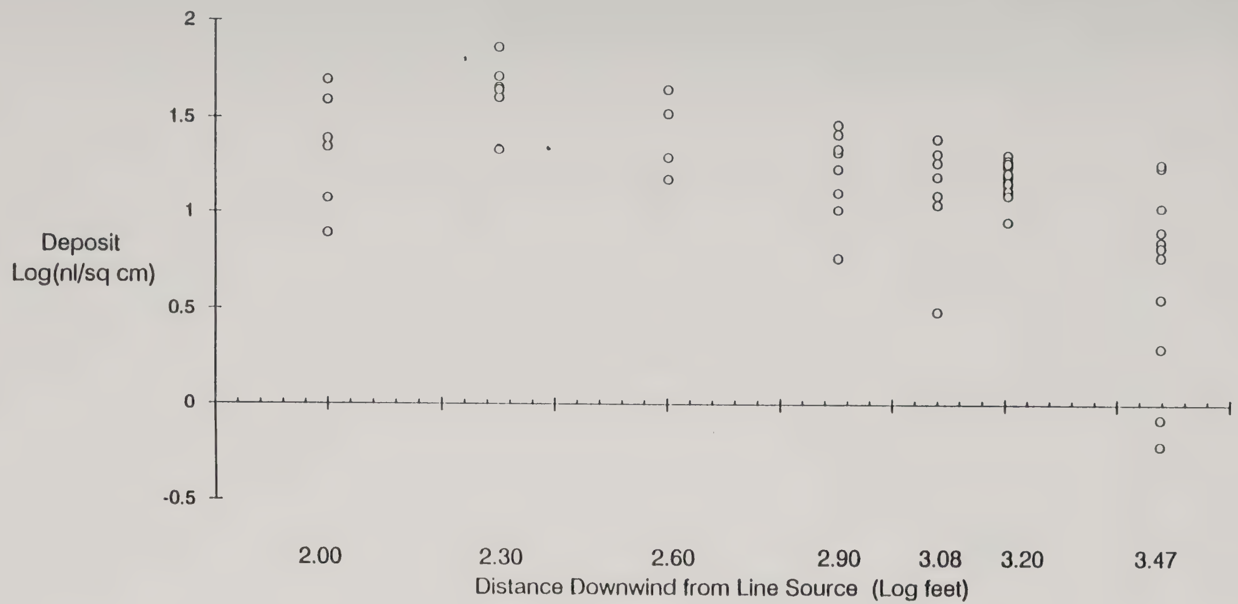

Figure 7a: Downwind spray deposit data expressed using a log transformation of nanolitres/cm^2 and distance downwind, collected using coarse aerosol flag samplers and corrected for collection efficiency, run 3, Mission, TX - 1985

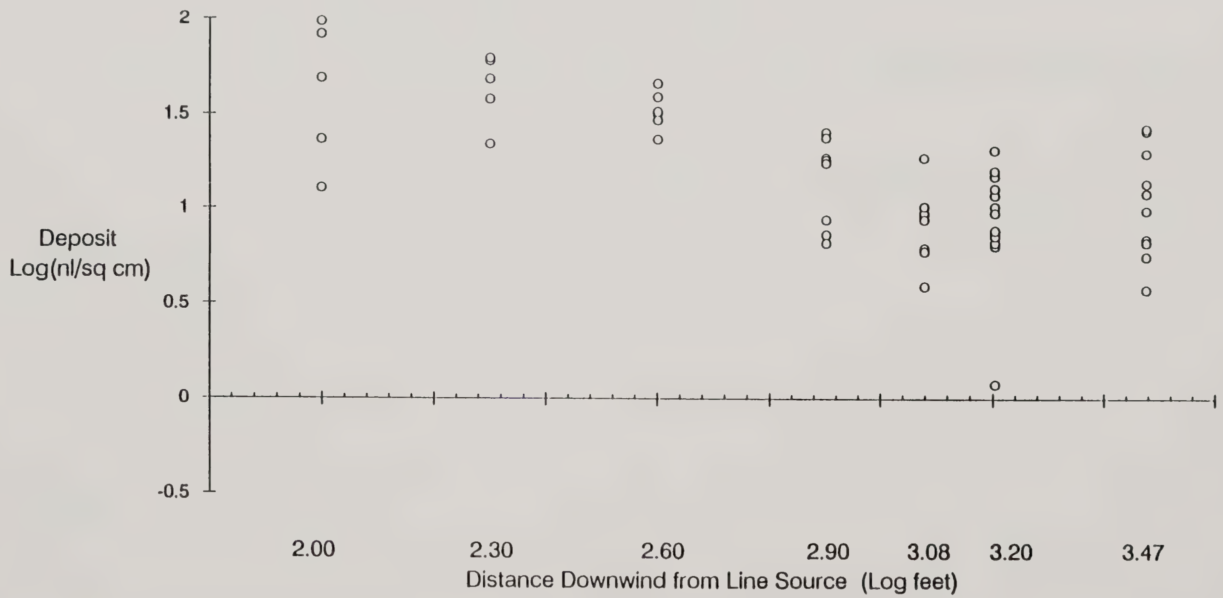

Figure 7b: Downwind spray deposit data expressed using a log transformation of nanolitres/cm^2 and distance downwind, collected using coarse aerosol flag samplers and corrected for collection efficiency, run 5, Mission, TX - 1985

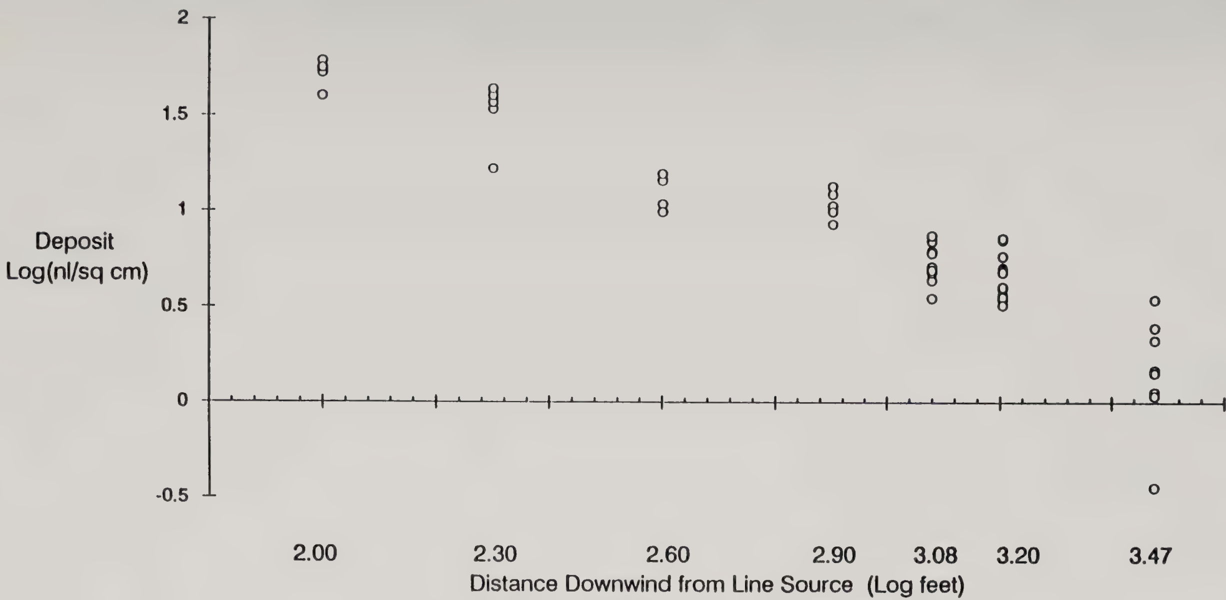

Figure 7c: Downwind spray deposit data expressed using a log transformation of nanolitres/cm^2 and distance downwind, collected using coarse aerosol flag samplers and corrected for collection efficiency, run 6, Mission, TX - 1985

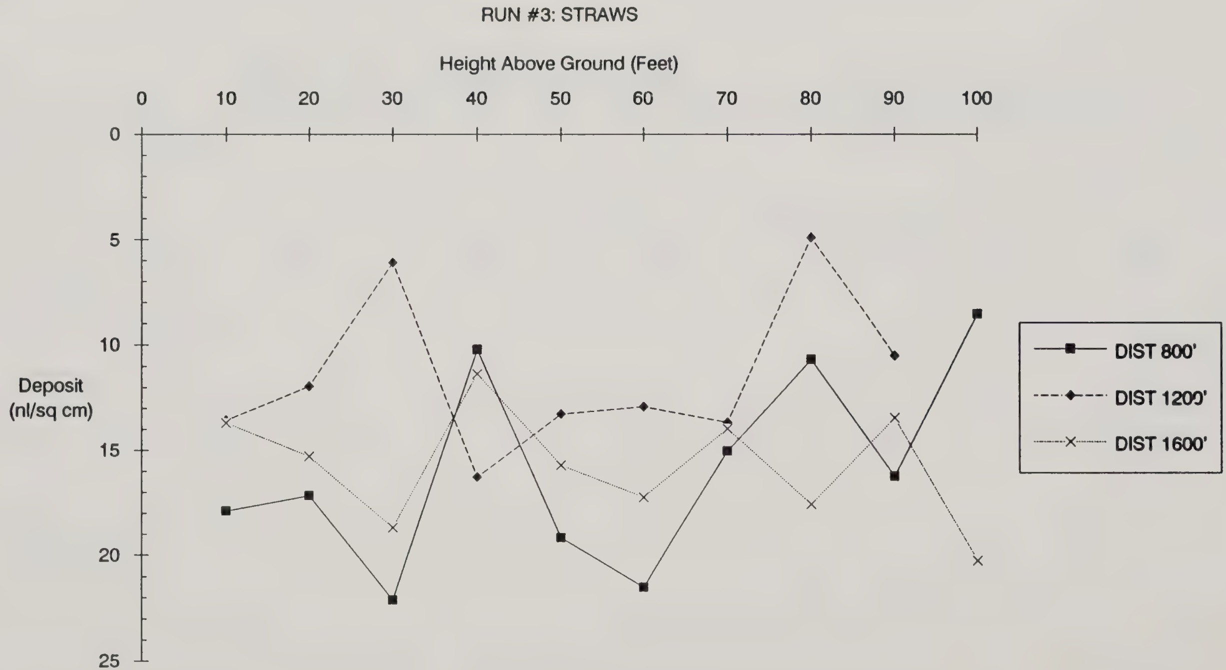

Figure 8a: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical plastic straws, run 3, Mission, TX - 1985

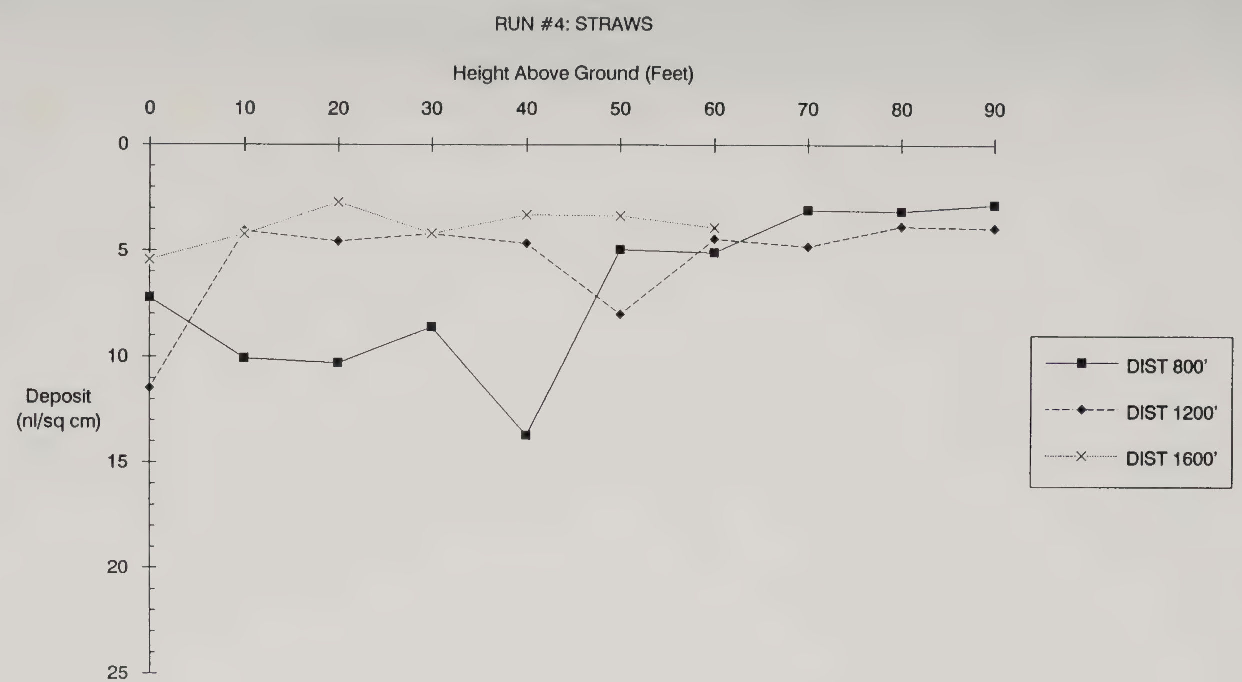

Figure 8b: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical plastic straws, run 4, Mission, TX - 1985

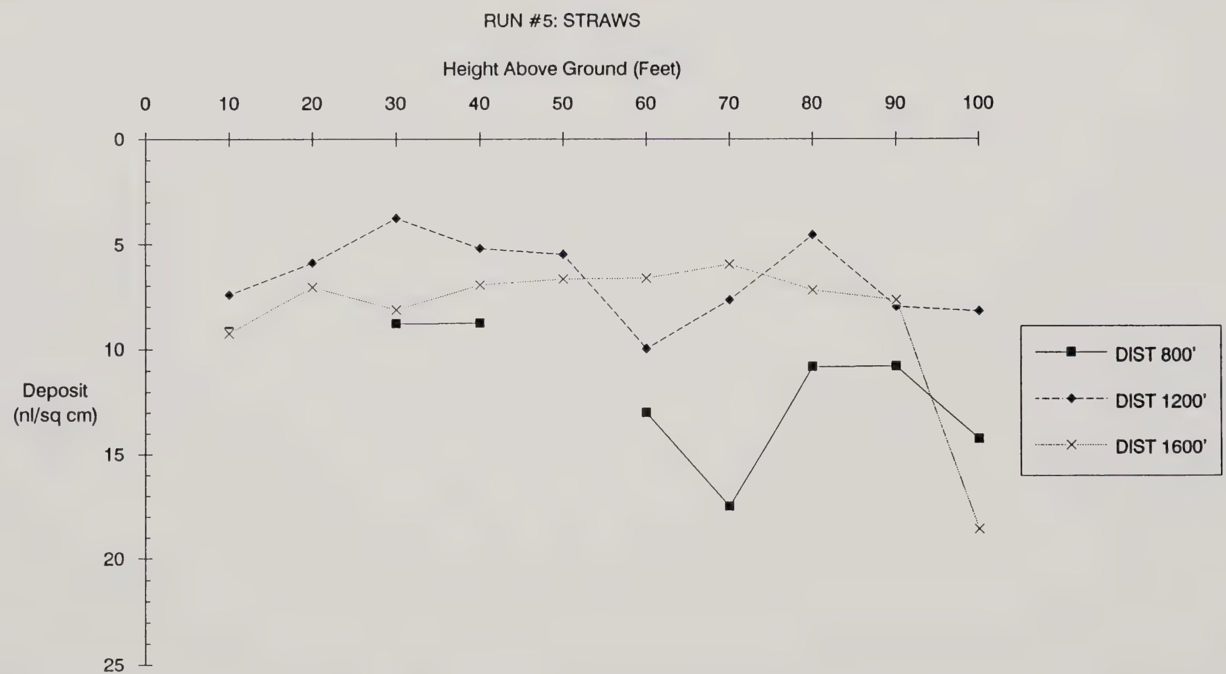

Figure 8c: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical plastic straws, run 5, Mission, TX - 1985

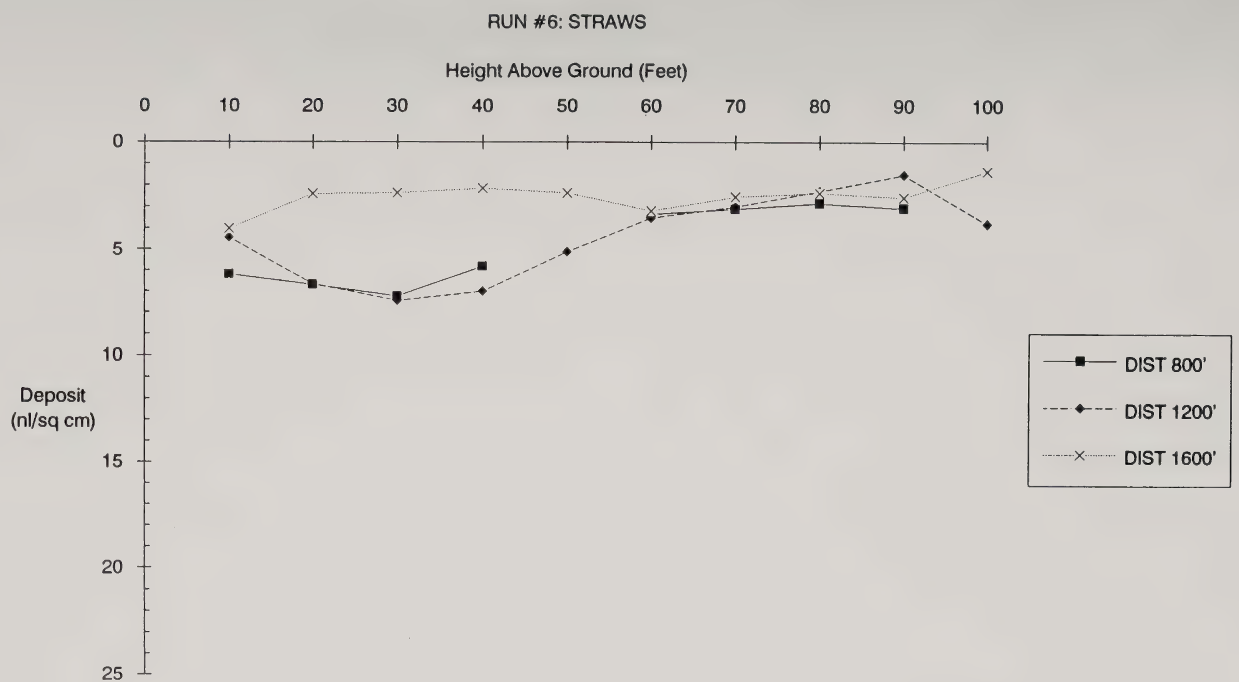

Figure 8d: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical plastic straws, run 6, Mission, TX - 1985

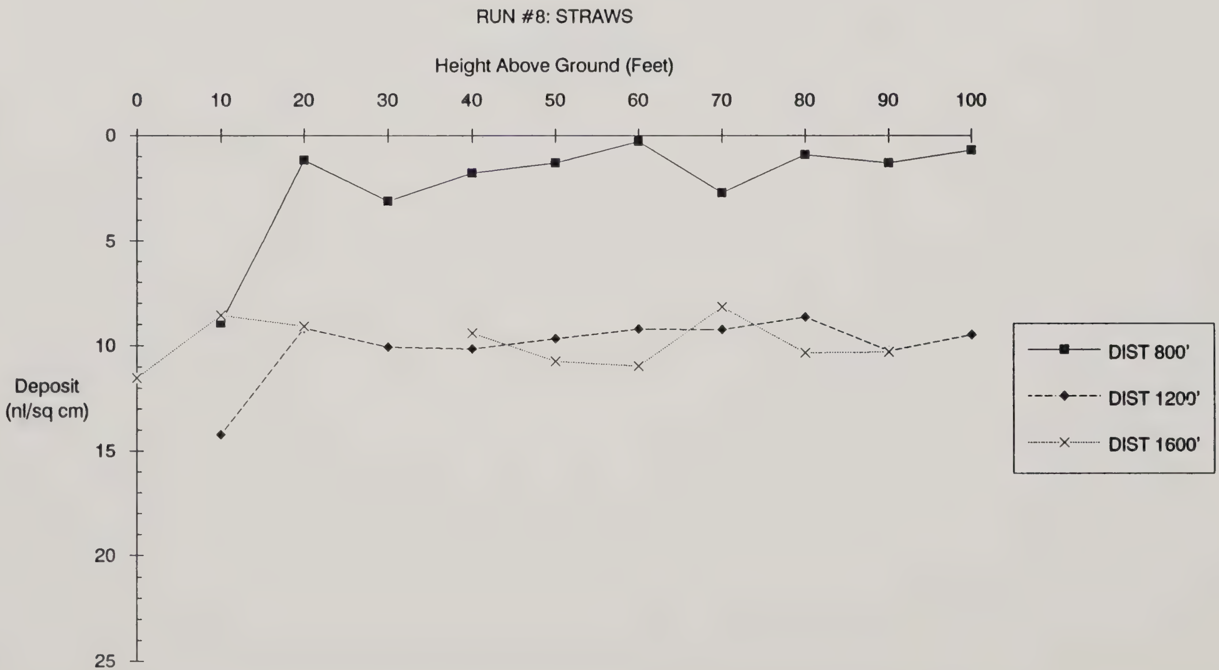

Figure 8e: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical plastic straws, run 8, Mission, TX - 1985

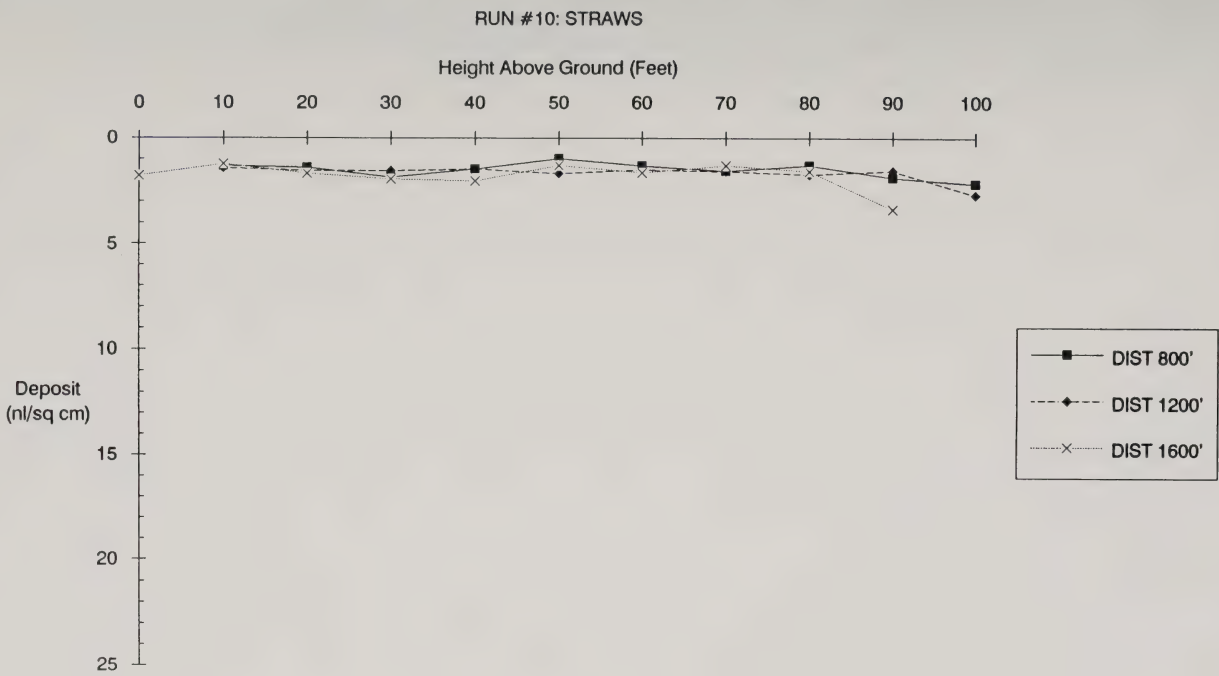

Figure 8f: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical plastic straws, run 10, Mission, TX - 1985

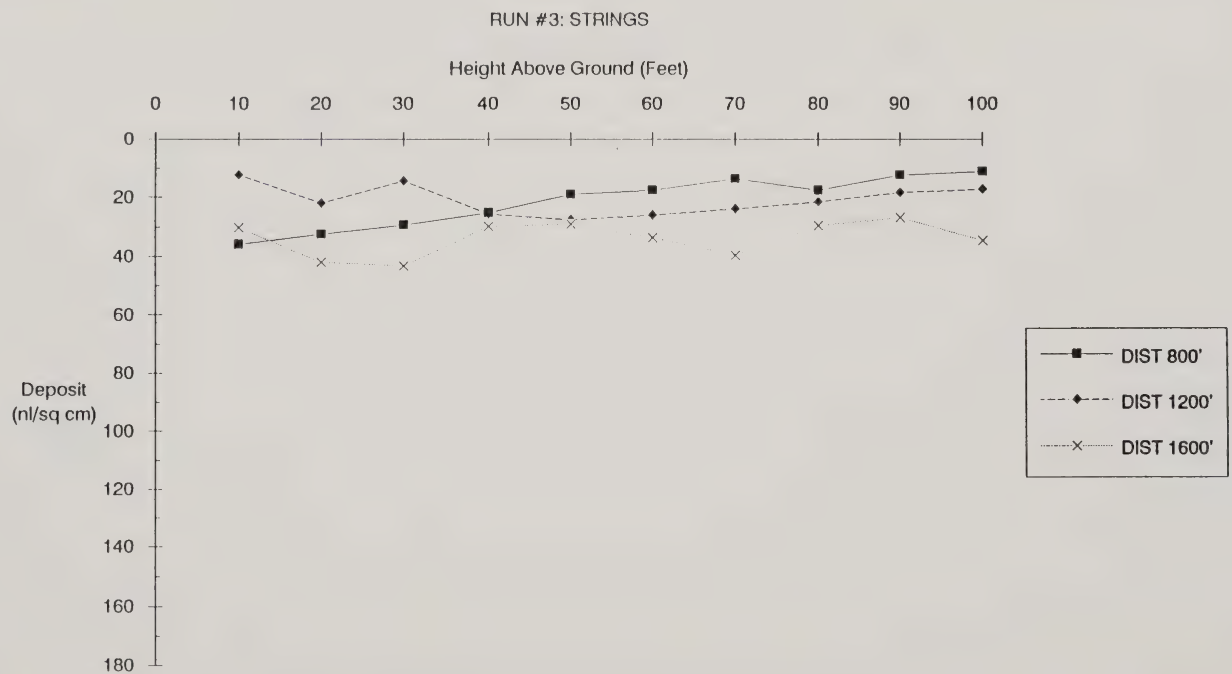

Figure 9a: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical cotton strings, run 3, Mission, TX - 1985

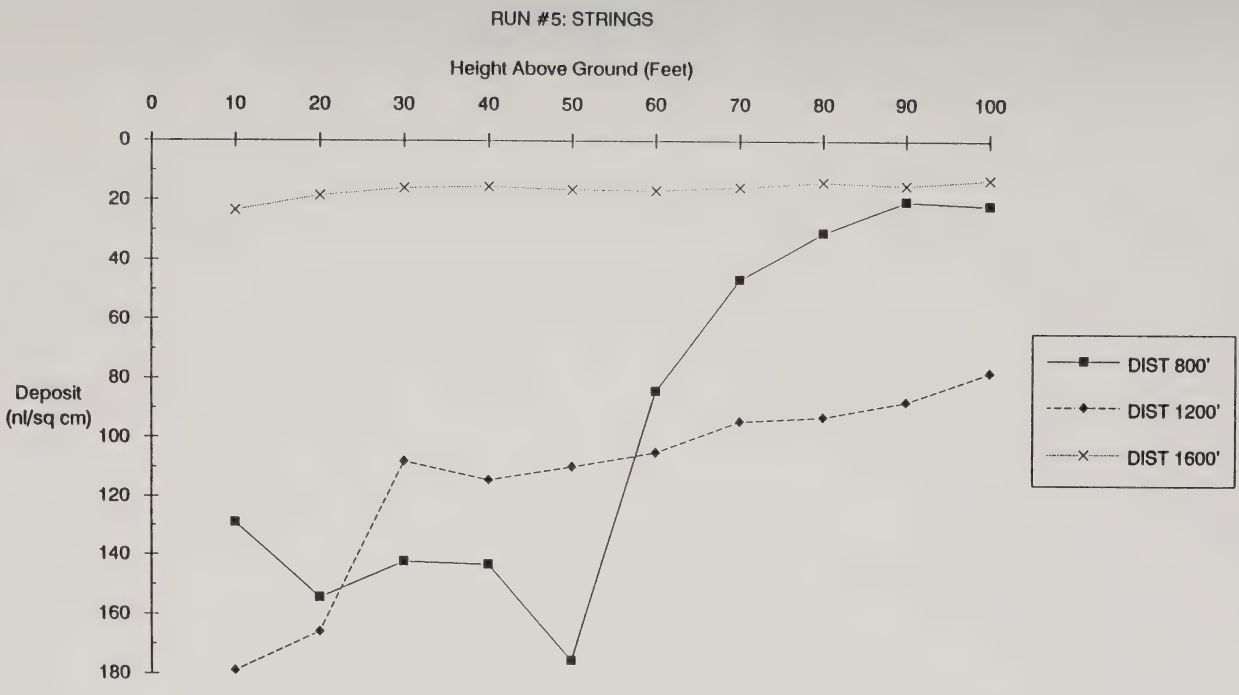

Figure 9b: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical cotton strings, run 5, Mission, TX - 1985

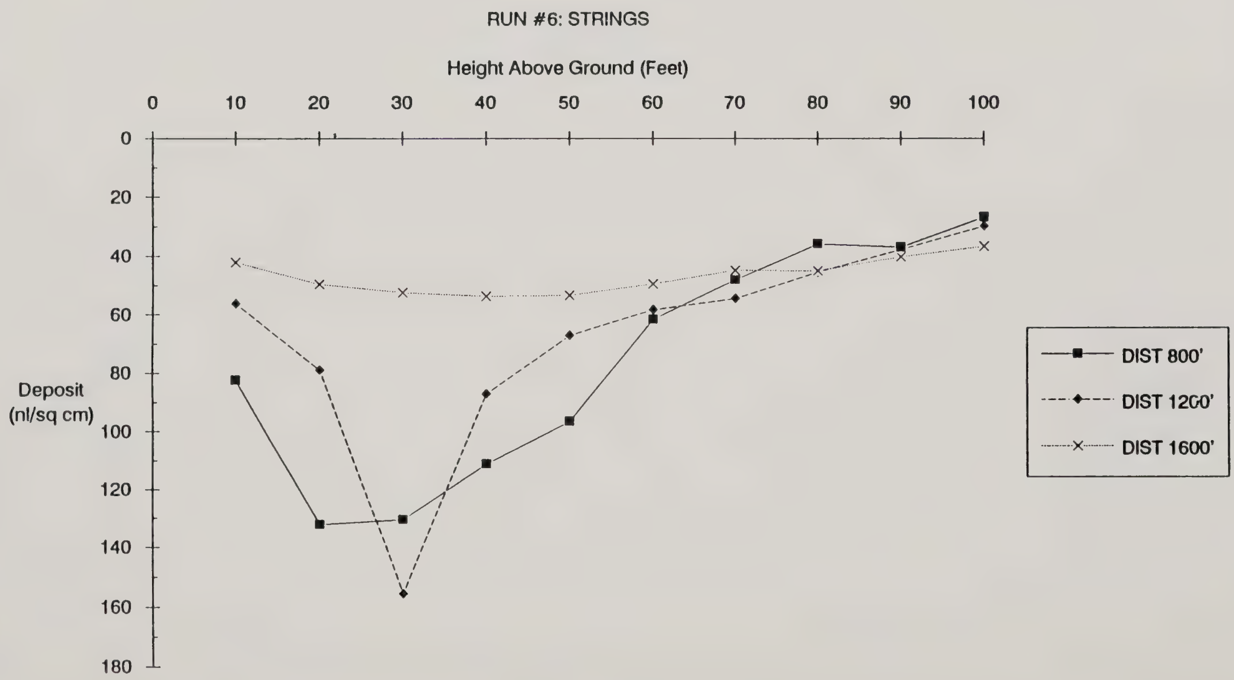

Figure 9c: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical cotton strings, run 6, Mission, TX - 1985

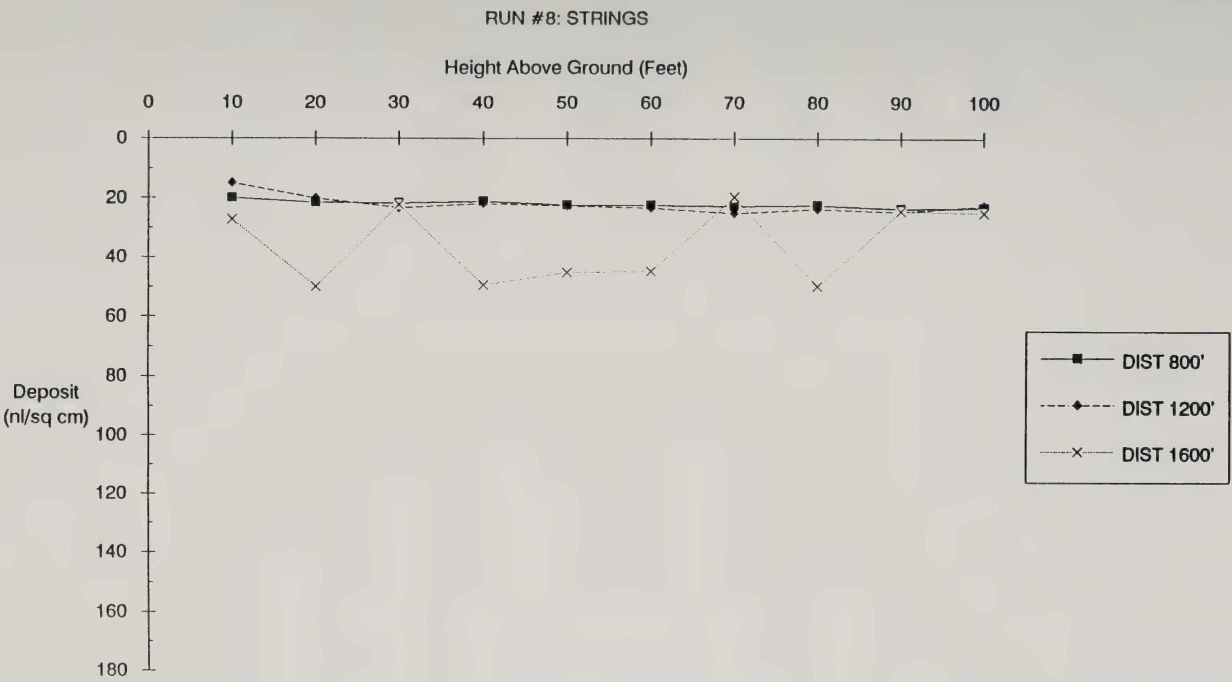

Figure 9d: Downwind spray deposit data expressed as nanolitres/cm^2, collected using vertical cotton strings, run 8, Mission, TX - 1985

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Pesticide Precautionary Statement

This publication reports the aerial application of insecticides. It does not contain recommendations for insecticide use, nor does it imply that the uses discussed here have been registered. All uses of insecticides must be registered by appropriate State and/or Federal agencies before they can be recommended.

Caution: Insecticides may be injurious to humans, domestic animals, desirable plants, and fish or other wildlife if they are not handled or applied properly. Use all insecticides selectively and carefully. Follow recommended practices for the disposal of surplus insecticides and insecticide containers.

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